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Comparative analysis of the usage of free-floating carsharing between Berlin and Calgary

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Vorwort

Verkehrsaktivitäten stehen in vielfältigen Wechselwirkungen mit ihrem wirtschaftlichen, ökologischen und sozialen Umfeld. Der Lehrstuhl für Verkehrsökologie beschäftigt sich in Forschung und Lehre mit diesen Wechselwirkungen, denn nur eine zusammenfügende Betrachtung kann sinnvolle und tragfähige Lösungen ergeben. Übergeordnetes Ziel aller Arbeiten des Lehrstuhls ist es, entsprechend der offiziellen Widmung „zur Verringerung der Umweltbelastungen aus dem Verkehr beizutragen". Schwerpunkte sind dabei Arbeiten zur Umsetzung einer nachhaltigeren Verkehrsentwicklung, die in folgenden Themenfeldern konkretisiert werden:

a) Nachhaltige Verkehrsentwicklung: Auswirkungen, Verfahren, Konsequenzen
b) Klimaschutz, Energie und CO_2 im Verkehr
c) Luftreinhaltung & Lärm, Emissionsfaktoren und reale Fahrmuster
d) Externe Kosten und Nutzen des Verkehrs, Kostenwahrheit und Internalisierung
e) Rad- und Fußverkehr
f) Umweltbildung, Monitoring und Evaluation
g) Soziale Exklusion und Umweltgerechtigkeit im Verkehrsbereich

Die Ergebnisse der dazu durchgeführten Untersuchungen sowie ausgewählter studentischer Arbeiten sollen im Rahmen dieser „Verkehrsökologischen Schriftenreihe" einer breiteren Öffentlichkeit zugänglich gemacht werden. Damit möchten wir einerseits die fachliche Diskussion zu Problemstellungen einer nachhaltigen Mobilitätsentwicklung und anderseits den offenen Zugang zu Wissen und Informationen unterstützen.

Die in dieser Veröffentlichung vorgestellte Studienarbeit von Frau Maren Schnieder führt einen internationalen Vergleich von stationsunabhängigen Carsharing-Systemen durch. Dabei wird die Stadt Calgary als sehr autoabhängige Stadt mit der Stadt Berlin als Vertreter einer weniger auto-zentrierten Stadt verglichen. Die Zielstellung ist, Erfolgsfaktoren für die weitere Implementierung von Carsharing in eher autoabhängigen Städten zu identifizieren.

In der Studienarbeit skizziert Frau Schnieder zunächst die strukturellen Unterschiede der beiden Städte. Kern der Untersuchung ist die nachfolgende Auswertung von realen Nutzungsdaten der Anbieter DriveNow und car2go einschließlich der Standorte des Fahrtbeginns und Fahrtende der Buchung. Anhand der Ergebnisse kann deutlich gezeigt werden, wie regulatorische Rahmenbedingungen die Nutzung von Carsharing begünstigen können. Dies kann sogar soweit führen, dass Wirkungen des Parkraummanagements durch Carsharing eingeschränkt werden. Somit zeigt die Studienarbeit deutlich, wie wichtig die Evaluation von verkehrsplanerischen Projekten ist.

Dresden, 18.04.2017 Udo Becker, Thilo Becker, René Pessier

TECHNISCHE UNIVERSITÄT DRESDEN

"Friedrich List" Faculty of Transportation and Traffic Sciences

COMPARATIVE ANALYSIS OF THE USAGE OF FREE-FLOATING CARSHARING BETWEEN BERLIN AND CALGARY

PROJECT THESIS

submitted in partial fulfillment of the requirements for the module

INDEPENDENT SCIENTIFIC WORK IN THE FIELD OF

TRANSPORT SYSTEMS ENGINEERING AND LOGISTICS

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EXECUTIVE SUMARY

Objectives: The purpose of this paper is to investigate possible reasons, based on economic and city characteristics, for the different usage of free-floating carsharing between a car-dependent city (Calgary) and one non-car-dependent city (Berlin). This paper identifies factors that help a free-floating carsharing system to be successful in a city that scores poorly on commonly known success factors of carsharing.

Methods: Various factors were evaluated, namely, geographic and demographic market characteristics, the available transport systems and the costs and household spending of both cities. A dataset which describes the usage of free-floating carsharing in Berlin and Calgary from August 2016 to November 2016 was analyzed in this study.

Results: Calgary's car2go system has fewer rentals and fewer members than Berlin. Possible reasons lie in the different city characteristics and different cost structures. Both 85th percentile of the travel distance is approximately as long as the radius of the respective home area in both cities. Thus, the median travel distance and the median reservation/rental duration is shorter in Calgary than in Berlin. The fact that more than 70 % of rentals in Calgary arrive in, depart from or travel within areas with active parking management could be due to the fact that free-floating carsharing users do not need to pay extra for parking fees. The carsharing bookings in Calgary peak at midnight when the public transportation service shuts down. The peak could also be the result of the high number of 3-minute long rentals at this time. Neither the high number of 3-minute bookings, the midnight peak, nor the public transport service close down during night, can be observed in Berlin. Given that employees in downtown Calgary may prefer to use free-floating carsharing to run errands during lunchbreak, the carsharing bookings do not plummet during midday, in contrast to Berlin, which only has a limited number of short distance rentals and where the free-floating carsharing bookings follow a similar pattern to the two-humped car traffic volume graph.

Conclusion: Given the focus of the departures and arrivals in Calgary in areas where parking fees are charged, active parking management could be a success factor for free-floating carsharing in car-dependent cities. However, it is not advisable to solely enforce parking fees within select parts of the home area as individuals generally prefer to use the less expensive mode of transport; which is free-floating carsharing to travel from and to areas with active parking management and their own car for any other trip. As a result, the city would not gain the benefits free-floating carsharing could provide.

Recommendations: Based on the results of this study, it is advisable to investigate whether home area wide or city wide parking management and surcharges for trips to downtown could encourage Calgary's members in to use the car2go in a way that it provides the most benefits from a city perspective.

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LIST OF ABBREVIATION

€	Euro
$	Canadian Dollar
USD	US Dollar

1. INTRODUCTION

The common belief is that carsharing works best in neighborhoods with low vehicle ownership and low mode share for cars (Kortum, et al., 2012 p. 22) (Celsor, et al., 2006 p. 9) (Stillwater, et al., 2009 p. 33). Indeed, the multimodality of New York City and Washington D.C. both of which are car2go cities, is 67 % and 55 %, respectively (Badger, 2013). Accordingly, car2go has decreased the size of several home areas after realizing that their cars were idling much longer in the outer low-density neighborhoods than in the city center (Marits, 2016).

However, not every city of the 29 cities where car2go provides carsharing services (Global Communications car2go, 2016_b) is well known for being public transit and bike friendly: Austin, Columbus, and San Diego have a multimodality of less than 12 % (Badger, 2013). Admittedly, these cities have a rather small system in terms of membership (Daimler AG, 2016). The free-floating carsharing service in Austin originated from a cooperation between Daimler and the city of Austin, which provided city of Austin employees with access to car2go vehicles for both private and business-purpose trips. The city of Austin employees were allowed to rent the car2go vehicles for business trips free of charge; in exchange the city provided reserved parking spaces for car2go without charge. Later, other agencies joined and since May 2010 the service has been available to the public (Kortum, et al., 2012 p. 12). As the example of the city of Austin shows, it could be possible to convert carsharing systems that originate from a cooperation with the city, to a for profit operation. Undeniably, these car-dependent cities might not have the most profitable free-floating carsharing system but they seem to be profitable enough from a car2go perspective.

Given that a low multimodality, low transit services and low density are factors perceived to be detrimental to the success of a carsharing system (Millard-Ball, et al., 2005 p. 3), it might be advantageous to investigate why these unlikely carsharing candidate cities are still able to operate a free-floating system. This study focuses on an in-depth analysis of the city characteristics, transport systems and costs for individuals, instead of following the traditional approach of selecting a few cities and searching, based on a few variables, for significant differences or correlations. Additionally, the study determines the differences in the free-floating carsharing usage between a car-dependent and a non-car-dependent city in order to identify reasons why a car-dependent city, which scores poorly on commonly used variables affecting carsharing, can still have many free-floating customers.

Based on the results, factors which could increase the possibility of implementing free-floating carsharing services in highly car-dependent and low density neighborhoods are determined. The objective of this research is to provide a first step towards the development of guidelines for a city council that would like to ease the way for the implementation of a free-floating carsharing service in an area where providing good public transportation is not feasible and therefore the area is not likely to be suitable for a free-floating carsharing service.

Choosing the cities

The goal was to compare two cities that differ drastically in their city-structure and transport systems. The first city should be highly dense with a high mode share for alternative modes of transport. The second city should be the opposite with a high mode share for cars, high car availability, residents who live mostly in the suburbs and have access to inexpensive gasoline. Most importantly, both cities must have in common that their free-floating carsharing systems were founded at a similar time and both cities belong to the highest-ranking cities in terms of car2go customer numbers. One ideal pair of cities is Berlin and Calgary. Berlin has the highest number of car2go customers overall and Calgary has the second highest number in North America. Vancouver, the highest-ranking North American city based on the number of car2go members, was not chosen because gasoline prices (Canadian Automobile Association, n.d._b), multimodality (CH2M HILL Canada Limited, 2015 p. 4.4) and the population density (Statistics Canada, 2012) are higher than in Calgary. Further, 80 % of the metropolitan population of Calgary lives in car-dependent suburbs (Gordon, et al., 2014). Consequently, Calgary stands in stark contrast to Berlin from a city structure viewpoint.

Report outline

While the scope of research identifying reasons why free-floating carsharing systems are or are not successful is vast, this report focuses on factors that could affect the usage of free-floating carsharing services: demographic and geographic market characteristics; expenses and cost structures; as well as available transportation systems. Further, the study is limited to two cities.

Chapter 3 is divided into an analysis of the demographic and geographic market characteristics, which have been identified as having an effect on carsharing in previous literature, followed by an in-depth analysis of available transportation systems including but not limited to public transportation, car traffic, walking, biking, car- and ride-sharing as well as transportation network companies. The last part of this chapter compares the household spending as well as the cost of transportation between both cities. Chapter 4 gives an overview about the data, which is a description of the usage of free-floating carsharing service in both cities. The chapter includes an overview of the data cleaning process, limitations and an assessment of the data. Chapter 5 presents the results of the analysis of the usage of free-floating carsharing which examines the distance and duration of rentals, time of booking over the span of the day and the spatial distribution of departures and arrivals. Chapter 6 compares the results of the analysis and suggests possible reasons for the observed differences in free-floating carsharing usage. Chapter 7 offers concluding remarks and describes opportunities for additional related work.

Appendix outline

The attachment includes additional graphics and the code of the database queries used in this project. A copy of sources used in this study can be found on the attached CD.

2. BACKGROUND: COMPARISON OF BERLIN & CALGARY

This chapter compares Berlin and Calgary according to variables which have been identified to potentially have a relationship to stationary or free-floating carsharing in studies conducted in USA, Canada and Europe.

While most studies compared data about members and non-members (Steininger, et al., 1996) (Prettenthaler, et al., 1999) (Cervero, et al., 2002) (Lane, 2005) (Shaheen, et al., 2005) (Burkhardt, et al., 2006) (Morency, et al., 2008) (Loose, 2010) (Costain, et al., 2012), three studies focused on GIS based correlation or regression analyses. In detail, Celsor et al. (2006) evaluated the relationship between carsharing supply and neighborhood characteristics (Celsor, et al., 2006 p. 6) and Kortum et al. (2012) analyzed the relationship between city characteristics and the presence of a carsharing system (Kortum, et al., 2012). Stillwater et al. (2009) used multivariate regression to find the relationship between carsharing usage and neighborhood characteristics and build environment (Stillwater, et al., 2009). Burkhard at al. (2006), Lose (2010) and Costain et al. (2012) analyzed membership data of various providers (Burkhardt, et al., 2006) (Loose, 2010) (Costain, et al., 2012). Other studies compared membership data to non-member data (Steininger, et al., 1996) (Prettenthaler, et al., 1999). (Cervero, et al., 2002) (Lane, 2005) (Shaheen, et al., 2005) (Burkhardt, et al., 2006) (Morency, et al., 2008). Steiniger et al. (1996) and Prettenthaler et al. (1999) analyzed data from the same survey.

Given that a characteristic that applies to most members does not necessary apply to the entire city or neighborhood in which the members are living, the results of GIS based studies and studies that analyze member data sometimes differ (Celsor, et al., 2006 p. 12). Moreover, most studies have been focusing on stationary carsharing. Thus, there is no certainty that these variables influence the success of free-floating carsharing in the same way.

2.1 Geographic markets

2.1.1 Population

According to Kortum et al. (2012), larger cities are more likely to have a carsharing system. The mean of the population of cities with carsharing is with 939,000 people, more than twice as high as the mean of the population of cities without carsharing (442,000 people) (Kortum, et al., 2012 p. 21).

The population of Berlin is 3,443,100 (Amt für Statistik Berlin-Brandenburg, 2015_c p. 36), while Calgary has 1,082,235 inhabitants (Statistics Canada, 2013).

2.1.2 Population density

Whereas most researchers affirmed, that high density areas help carsharing to succeed (Cervero, et al., 2004) (Burkhardt, et al., 2006 p. 105) (Celsor, et al., 2006 p. 5) (Costain, et al., 2012 p. 5), two of the three GIS based studies concluded that density appears not to play an important role in the success of a carsharing (Stillwater, et al., 2009 p. 32) (Kortum, et al., 2012 p. 22). Celsor at al. (2006) assert, as a guide line, that an area should have at least 5 housing units per acre[1] (Celsor, et al., 2006 p. 13); however, most carsharing neighborhoods have 7 to 25 housing units per acre[2] (Celsor, et al., 2006 p. 8).

The population density in Berlin is 3,891.3 people per square kilometer (2014) (Amt für Statistik Berlin-Brandenburg, 2015 a p. 30) whereas Calgary has a population density of 1,329.0 people per square kilometer (Statistics Canada, 2013). Based on an average household size of 1.7 people in Berlin (Amt für Statistik Berlin-Brandenburg, 2015_b) and 2.6 people in Calgary (Statistics Canada, 2013) the household density is 2,211 households per square kilometer in Berlin and 511 households per square kilometer in Calgary.

2.2 Demographic markets

2.2.1 Household size and children

Research has given ample support for the assertion that smaller average household sizes have a positive effect on carsharing memberships (Cervero, et al., 2002 p. 14) (Cervero, et al., 2004 p. 121) (Lane, 2005 p. 160) (Celsor, et al., 2006 p. 9) (Burkhardt, et al., 2006 p. 104) (Loose, 2010 p. 47) (Kortum, et al., 2012 p. 22). Celsor at al. (2006) specifies as a threshold that a city where 40 % to 50 % of households are one person households, is likely to be suitable for carsharing (Celsor, et al., 2006 p. 13). Contrary, Steiniger et al. (1996) and Prettenthalera et al. (1999) did not find a significant difference between the household size of members and the general population (Steininger, et al., 1996 p. 179) (Prettenthaler, et al., 1999 p. 446).

Celsor at al. (2006) ascertained that the level of carsharing service is higher in areas with a low percentage of household with children (Celsor, et al., 2006 p. 9). Further, Prettenthalera et al. (1990) and Steiniger et al. (1996) added that if carsharing participants have children, they tend to have a higher number of children (Prettenthaler, et al., 1999 p. 446) (Steininger, et al., 1996 p. 179).

31.2 % of households are one person households and 82.3 % of the households in Berlin are one or two person households (Amt für Statistik Berlin-Brandenburg, 2015_b) whereas in Calgary only 10.1 % of households are one person households and 58.2 % of households are single or two-person household (Statistics Canada, 2013). Therefore, approximately 63.5 % of people in Berlin live alone or with another person compared to 35.3 % in Calgary.

2.2.2 Household income

There seems to be no agreement regarding household income. Most research believed that people with high income are amenable to carsharing (Steininger, et al., 1996 p. 179) (Shaheen, et al., 2005 p. 48) (Cervero, et al., 2004 p. 121) Burkhardt et al. (2006) observed that cost-sensitivity is an additional characteristic shared by most carsharing members

[1] 1,235 housing units per square kilometer

[2] 1,729 housing units per square kilometer to 6,175 housing units per square kilometer

(Burkhardt, et al., 2006 p. 104). On the contrary, Cervero et. al. (2002) reported that carsharing participants tend to earn close to the median income of the city (Cervero, et al., 2002 p. 36) while others proposed, that the majority of carsharing members earn a middle income, followed by high income, and then low income (Lane, 2005 p. 160). Celsor et al. (2006) and Kortum et al. (2012) could not confirm that a high-income level in the neighborhood or city correlates with carsharing (Celsor, et al., 2006 p. 9) (Kortum, et al., 2012 p. 22).

Table 2-1: After-tax income of individuals

Berlin **After tax Income per year**	**%**	**Calgary** **Income per year**	**%**
Without after-tax income	14,7%	Without after-tax income	5,0%
Under 3,600 €	4,0%	Under $5.000	9,9%
3,600 € to 6,000 €	4,9%	$5.000 to $9.999	5,9%
6,000 € to 8,400 €	6,8%	$10.000 to $14.999	6,9%
8,400 € to 10,800 €	10,5%	$15.000 to $19.999	7,1%
10,800 € to 13,200 €	9,8%	$20.000 to $29.999	12,9%
13,200 € to 15,600 €	9,9%	$30.000 to $39.999	12,8%
15,600 € to 18,000 €	8,3%	$40.000 to $49.999	10,9%
18,000 € to 24,000 €	14,1%	$50.000 to $59.999	7,7%
24,000 € to 31,200 €	8,5%	$60.000 to $79.999	9,9%
31,200 € and over	8,5%	$80.000 to $99.999	4,5%
		$100.000 and over	6,4%

Source: (Amt für Statistik Berlin-Brandenburg, 2015_c p. 14) (Statistics Canada, 2013)

Table 2-2 After-tax income of households

Berlin **After tax Income per year**	**%**	**Calgary** **Income per year**	**%**
0 € to 10.800 €	12,3%	Under $5.000	3,0%
10.800 € to 15.600 €	15,2%	$5.000 to $9.999	1,3%
15.600 € to 18.000 €	7,0%	$10.000 to $14.999	2,1%
18.000 € to 24.000 €	15,8%	$15.000 to $19.999	3,0%
24.000 € to 31.200 €	15,4%	$20.000 to $29.999	6,4%
31.200 € to 43.200 €	15,9%	$30.000 to $39.999	8,2%
43.200 € to 60.000 €	9,4%	$40.000 to $49.999	9,0%
60.000 € to 216.000 €	8,9%	$50.000 to $59.999	8,7%
		$60.000 to $79.999	15,9%
		$80.000 to $99.999	12,4%
		$100.000 to $ 124.999	10,9%
		$ 124,999 and over	19,0%

Source: (Amt für Statistik Berlin-Brandenburg, 2016 p. 18) (Statistics Canada, 2013)

2.2.3 Vehicle ownership

The consensus view is that low vehicle ownership in a neighborhood is a good variable to predict both membership and carsharing usage (Steininger, et al., 1996 p. 179) (Prettenthaler, et al., 1999 p. 446) (Cervero, et al., 2002 p. 15) (Lane, 2005 p. 160) (Celsor, et al., 2006 p. 9) (Burkhardt, et al., 2006 p. 100) (Stillwater, et al., 2009 p. 33) (Loose, 2010 p. 48). Celsor at al. (2006) determined as a threshold, that 35 % to 40 % of households should not have a vehicle, and 70-80% should have less than one vehicle (Celsor, et al., 2006). In contrast, Kortum et al. (2012) could not identify a correlation between vehicle ownership and whether or not a city has a carsharing program (Kortum, et al., 2012 p. 22). Shaheen et al. (2005) did not found a significant difference to the normal population (Shaheen, et al., 2005 p. 48).

Berlin has 0.65 cars per household (Ahrens, et al., 2015 p. tab 9) and 324 cars per 1,000 people (Senatsverwaltung für Stadtentwicklung und Umwelt Kommunikation, 2014 p. 21) whereas Calgary has 1.85 cars per household (City of Calgary, 2013 p. 28) and 735 cars per 1,000 people (City of Calgary Transportation Planning, 2008 p. 1).

Table 2-3: Cars per household

	Berlin	Calgary
0 car	39.8 %	5.5 %
1 car	49.3 %	35.5 %
2 cars	-	40.1 %
2 or more cars	10.9%	-
3 or more cars	-	18.9 %

Source: (Ahrens, et al., 2015 p. tab 9) (City of Calgary, 2012 p. 31)

2.2.4 Mode share

The available evidence corroborates that a low mode share of cars seems to make a city more amenable to carsharing. Accordingly, a high percentage of transit share is perceived to be a good indicator (Lane, 2005 p. 160) (Kortum, et al., 2012 p. 22) (Cervero, et al., 2002 p. 8) (Celsor, et al., 2006 p. 9). While the mode share of walking correlates with the carsharing level of service, the mode share of or bicycles has not proven to correlate (Celsor, et al., 2006 p. 9)

Table 2-4: Mode share

	Berlin	Calgary	
	All day based on ways	All day based on ways	Downtown am peak inbound
Walked	31,0 %	5.1 %	9 %
Bicycle	12,5 %	1.3 %	2 %
Car	29,6 %	75.1 %	33 %
Public Transport	26,9 %	17.2 %	50 %
other	-	1.3 %	-
Car passenger	-	-	6 %

Source: (Ahrens, et al., 2015 p. tab 12) (Statistics Canada, 2013) (City of Calgary Transportation Planning, 2012)

2.3 Comparison of transport systems

2.3.1 Walking

The Walk Score, which measures the walkability of a neighborhood (Walk Score, n.d._c), is 48 out of 100 in Calgary which means that Calgary is a car-dependent city (Walk Score, n.d._b). Given that Germany is an unsupported country by the Walk Score company, the Walk Score in Berlin is solely calculated based on the distance to amenities. Based on this methodology Berlin has a Walk Score of 98 out of 100 (Walk Score, n.d._a).

2.3.2 Bicycle

In Berlin Nextbike GmbH offers hourly and daily bike sharing service and the bikes can be returned to any Nextbike station in the city (nextbike GmbH, n.d.). The same was offered until November 2016 by Call a bike which is due to be replaced by Lidl-Bike from spring 2017 onwards (DB AG, n.d.). Bikesurfing offers free bike rentals for one week in Berlin (Barkhau, n.d.). Bicycles are permitted on public transport but subject to available space and in most cases an additional fare is charged (Berliner Verkehrsbetriebe, n.d._a) (S-Bahn Berlin, n.d.) (VBB Verkehrsverbund Berlin-Brandenburg GmbH, n.d.). Approximately 50 % (800 km) of the main roads in Berlin have a bike path (Borufka, 2016), whereas Calgary has only 30 km of on-street marked bike lanes. Additionally, bicycle riders in Calgary can ride on 700 km multiple-use pathways (MUP) in parks which are designed for recreational users and therefore have a set speed limit of 10 or 20 km/h (BikeCalgary.org, n.d.). People, affiliated with the University of Calgary can rent a bicycle for two days or a week for a reasonable price (University of Calgary, n.d). In contrast to Berlin, free-floating or stationary bike sharing is not available in Calgary. Bicycles are allowed for free on one of 50 buses that are equipped with bike racks and on C-trains except at rush hour (City of Calgary, n.d._a) (Sustainable Calgary, 2015).

2.3.3 Public transportation

Table 2-5: Public transportation in Berlin and Calgary

	Berlin	Calgary
Ridership	Bus and Ferris: 405 mio. [A] Tram: 181.1 mio. [A] Underground: 517.4 mio. [A] Heavy rail: 413.9 mio. [C] Regional lanes: 33.6 mio. [C]	C-Train and Bus combined: 110 mio. [B] [E]
Service hours	Bus: 4.55 mio. h [C] Tram: 1 mio. h [C] Ferry: 17,500 [I]	Service hours 2.85 mio [B]
Average trip length	10.3 km [G]	14.7 km [E]
Number of lines at day time	Bus: 151 [A] [C] 169 [I] Tram: 22 [A] [C] 24 [I] Underground: 10 [A] [C] [I] Heavy rail: 15 [C] [I] Regional lanes: 21 [C] [I] Ferris: 5 [C] [I]	Bus: 161 [B] 159 [E] School Bus: 110 [B] C-Train: 2 [B]
Service at night	Reduced service by BVG [A];	No service [F]

time	no service by the heavy rail on weekday nights [H].	
Number of stops and stations	Bus: 6,454 [A] [C] Tram: 808 [A] [C] Underground: 173 [A] [C] [I] Heavy rail: 133 [C] Regional lanes: 21 [C]	C-Train: 45 [B] [E]
Route coverage	Bus: 1725 km [C] Tram: 295.7 km [A] [C] Underground: 146.3 [A] [C] Heavy rail: 256.2 km [C] Regional lanes: 204.6 km [C]	Bus: 3864 km [B] [E] C-Train: 59.9 km [B] [E]
Number of Vehicles/cars	Bus: 1,321 [A] Tram: 353 [A] Underground: 1238 [A] Heavy rail: 650 [D]	Bus: 971 [B] C-Train: 192 [B]
Park and ride facilities	Park and ride lots: 47 [J] Parking spaces: 5,140 [J]	Park and ride lots: 35 [E]

[A] (Berliner Verkehrsbetriebe, 2014 pp. 1-2)
[B] (McDaniel, 2016 pp. 2-3)
[C] (Center Nahverkehr Berlin, 2016)
[D] (Senatsverwaltung für Stadtentwicklung und Umwelt Kommunikation, 2014 pp. 49-55)
[E] (Calgary Transit, n.d._c)
[F] (TransCanada FoundLocally Inc., n.d)
[G] (Ahrens, et al., 2015 p. tab 17)
[H] (BerlinOnline Stadtportal GmbH & Co. KG, n.d._a)
[I] (VBB Verkehrsverbund Berlin-Brandenburg GmbH, 2015 pp. 26-42)
[J] (Rikus, et al., 2015 p. 97)

2.3.4 Car traffic

The TOMTOM Traffic index, which is defined as the increase in travel time compared to a free float situation, is 28 % in Berlin compared to 19 % in Calgary. While the travel time prolongs during the morning and evening rush hour in Berlin by 42 % and 49 %, the morning and evening peaks are 28 % and 39 % in Calgary (TomTom International BV, 2015). Most parts of the downtown area of both cities have active parking management including residential parking zones (Senatsverwaltung für Stadtentwicklung und Umwelt Kommunikation, 2014 p. 29) (Calgary Parking Authority, n.d._a) (Senatsverwaltung für Stadtentwicklung und Umwelt, n.d.) (City of Calgary, n.d._b). In Berlin 39.8 % of households do not have a car (Ahrens, et al., 2015 p. 9 a) compared to 5.5 % in Calgary (City of Calgary, 2012 p. 31).

2.3.5 Stationary and free-floating carsharing

Berlin has six stationary carsharing providers which have a total of 559 cars and three free-floating carsharing providers (Senatsverwaltung für Stadtentwicklung und Umwelt Kommunikation, 2014). Additionally, Drivy and Tamycar offer private (peer-to-peer) carsharing, and eMio offers 150 scooters for free-floating rent (carsharing news, 2016). Although having stationary carsharing services in the past (Beltline Urban Society, n.d.), Calgary does not have a stationary carsharing service at present (City of Calgary, n.d._d).

Table 2-6: Comparison of car2go and DriveNow in Berlin and car2go in Calgary

	Berlin		Calgary
	DriveNow	**car2go**	**car2go**
Found	Sept. 2011 [A]	April 2012 [D]	July 2012 [D]
Members	200,000 (Sept. 2016) [A]	141.000 Oct 2016 [E]	100,000 (Nov. 2016) [F]
Home area	160 km² [A]	160 km² [D]	80 km² [D]
Changes in the home area	April 2012 increase [A] Aug 2012 increase [A] Sept. 2012 increase [A] Aug. 2013 increase [A] Mar. 2016 increase [B]	June 2013 increase [G] April 2014 decrease [H] Aug. 2015 decrease [I]	Sept. 2015 decrease [J] Dec. 2016 increase [X]
Vehicles	1300 (Nov. 2016) [C]	1.100 (Dec. 2016) [D]	600 (Dec. 2016) [D]

[A] (DriveNow, 2016_b pp. 3-4)
[B] (DriveNow, 2016_a)
[C] (DriveNow, n.d._b)
[D] (Global Communications car2go, 2016_b p. 1)
[E] (Global Communications car2go, 2016_a)
[F] (car2go N.A., LLC, 2016)
[G] (Peez, 2013)
[H] (Carsharing News , 2014)
[I] (Rogalla, 2015)
[J] (Potkins, 2015)
[X] (CBC/Radio-Canada, 2016)

2.3.6 Ridesharing

The city of Calgary promotes Carpool, which is an online platform that connects people who would like to share their commute regularly (City of Calgary, n.d._d), nothing similar is done in Berlin.

2.3.7 Transportation network companies, taxi and limousines, designated drivers

The fares of taxis, but not the number of taxi licenses, is regulated in Berlin (Deutscher Industrie- und Handelskammertag, 2014 p. 3). During evening and night hours, Allygator shuttle as well as CleverShuttle offer a shuttle service within the Berlin Ringbahn since summer 2016. A customer requests a ride via the app, and the company matches the ride with other journey requests. Those riders will then share a shuttle (allygator shuttle, n.d.) (CleverShuttle, n.d._a). With UberTAXI and UberX-option a customer can request a ride either in a regular taxi or in a limousine (Uber Technologies Inc., n.d_a).

While in Calgary the number of taxi licenses available and the maximum fare is set by the Livery Transport Services, each company can set their fares individually since April 2016 (City of Calgary, 2016 p. 66). Since then taxi companies decreased their fares by between 12 % and 15 % (Southwick, 2016). According to a report to the Livery Transport Advisory 91 % of all taxis arrive within 15 minutes, which means that they exceed the target Dispatch Response Time of 85 % within 15 minutes (Henriques, 2016). Although the maximum fare for taxis does not apply to transportation network companies such as Uber, these companies as well as their drivers must meet safety and administrative requirements (City of Calgary, n.d._e). UberX started their service on December 6, 2016 in Calgary (Uber Technologies Inc., 2016). Additionally, Calgary is serviced by six designated driver programs. Those drivers drive the customer and their car home if the driver cannot drive anymore due to a medical treatment, or alcohol consumption (Alberta Motor Association (AMA), 2016).

2.4 Comparison of the cost of transport and household spending

Table 2-7: Comparision of the cost

	Berlin				Calgary		
	Cost	**% of median income** a)	**source**		**Cost**	**% of median income** a)	**source**
		2,471 €	[1]			$ 5,841.5	[2]
Public transport							
Single fare	2.70 €	0.11%	[A]	**Single fare**	$ 3.15	0.05%	[B]
Monthly ticket	81.00 €	3.28%	[A]	**Monthly ticket**	$ 99.00	1.69%	[B]
3 most sold cars							
VW Golf per month b)	541.00 €	21.89%	[C] [D] [E] [F]	**Ford F-Series per month** b)	$ 315.25	5.40%	[G] [H] [I] [J]
VW Passat Variant per month b)	651.00 €	26.35%	[C] [D] [E] [F]	**Ram Pick up per month** b)	$ 328.50	5.62%	[G] [H] [I] [J]
VW Polo per month b)	398.00 €	16.11%	[C] [D] [E] [F]	**Honda Civic per month** b)	$ 245.42	4.20%	[G] [H] [I] [J]
Most sold car of the other country							
Honda Civic per month	485.00 €	19.63%	[C] [D] [E] [F]	**VW Golf**	$ 265.17	4.54%	[G] [H] [I] [J]
Average gasoline price							
Cost per l	1.41 €	0.06%	[K]	**Cost per l**	$ 0.90	0.02%	[G]
Parking							
15 minutes parking min	0.25 €	0.01%	[L]	**Per hour mean**	$ 7.00	0.12%	[M] [N]
15 minutes parking max	0.75 €	0.03%	[L]	**Per day mean**	$ 25.00	0.43%	[M] [N]
Taxi							
Base Fare	3.90 €	0.16%	[O]	**First 120 meters**	$ 3.80	0.07%	[P]
Cost per km (1-7 km)	2.00 €	0.08%	[O]	**Each additional km** d)	$ 1.67	0.03%	[P]
Each additional km	1.50 €	0.06%	[O]				
Cost per hour waiting	30.00 €	1.21%	[O]	**Waiting charges per hour:**	$ 33.80	0.58%	[P]
Estimated cost for a 10-km trip	22.40 €	0.91%	[O]	**Estimated cost for a 10-km trip**	$ 20.00	0.34%	[P]

Table c.f.

Uber (UberTAXI in Berlin and UberX in Calgary)							
Base Fare	5.40 €	0.22%	[Q]	**Base Fare**	$ 1.30	0,02%	[R]
cost per km 1-7 km	2.00 €	0.08%	[Q]	**Cost per minute**[e)]	$ 0.17	< 0,01%	[R]
cost per km from 7 km	1.50 €	0.06%	[Q]	**Cost per km**	$ 0.90	0,02%	[R]
Cost per hour waiting	30.00 €	1.21%	[Q]	**Booking Fee**	$ 2.15	0.04%	[R]
				Minimum Fare[f)]	$ 5.45	0,09%	[R]
Estimated cost for a 10-km trip	23.90 €	0.97%	[Q]	**Estimated cost for a 10-km trip**[g)]	$ 12.00 - $ 16.00	0,21% - 0,27%	[R]
Designated driver (Drive Smart)							
				Estimated cost for a 10-km trip	$ 43.56	0.75%	[T]
Aligator Taxi							
Cost per km	0.05 €	< 0.01%	[U]				
Estimated cost for a 10-km trip	0.50 €	0.02%	[U]				
Free-floating carsharing (Car2go)[h)]							
Cost per minute driving	0.24 €	0.01%	[V]	**Fare per minute driving**	$ 0.51	0.01%	[W]
Cost per minute parking	0.19 €	0.01%	[V]	**Cost per minute parking**	$ 0.51	0.01%	[W]
Cost per hour	13.99 €	0.57%	[V]	**Per hour**	$ 15.74	0.27%	[W]
Airport drop off/pick up	4.90 €	0.20%	[V]	**Airport drop off/pick up**	$ 13.13	0.22%	[W]
Estimated cost for a 10-km trip	6.15 €	0.25%	[V]	**Estimated cost for a 10-km trip**	$ 10.29	0.18 %	[W]
Stationary Carsharing (Greenwheel)							
Per hour (day time / small)	1.99 €	0.08%	[X]				
Per km small car	0.25 €	0.01%	[X]				
Estimated cost for a 10-km trip with a 2 h stopover	3.35 €	0.14%	[X]				
Bike sharing (next bike)							
30 minutes	1.00 €	0.04%	[Z]				

Table c.f

Scooter eMio							
Cost per minute [i]	0.19 €	0.01%	[Y]				
Cost per km [i]	0.59 €	0.02%	[Y]				
Idle time cost per hour	3.00 €	0.12%	[Y]				
Estimated cost for a 10-km trip [i]	4.87 €	0.20%	[Y]				

Source:

[1] (Amt für Statistik Berlin-Brandenburg, 2015_c p. 14)
[2] (Statistics Canada, 2013)
[A] (Berliner Verkehrsbetriebe, n.d._b)
[B] (Calgary Transit, n.d._a)
[C] (ADAC Fahrzeugtechnik, 2016 pp. 39-41)
[D] (Auto News Medien GmbH, 2015)
[E] (Baumann, Uli, 2016)
[F] (Auto Bild, 2015)
[G] (Canadian Automobile Association, n.d._a)
[H] (GoodCarBadCar, 2016)
[I] (focus2move, 2016)
[J] (The Globe and Mail Inc, 2016)
[K] (Drahn, 2016)
[L] (BerlinOnline Stadtportal GmbH & Co. KG, n.d._a)
[M] (Colliers International, 2012)
[O] (BerlinOnline Stadtportal GmbH & Co. KG, n.d._c)
[P] (City of Calgary, n.d._f)
[Q] (Uber Technologies Inc., n.d_a)
[R] (Uber Technologies Inc., n.d._b)
[T] (Drive Smart Designated Drivers, n.d.)
[U] (allygator shuttle, a).
[V] (car2go, n.d._c)
[W] (car2go, n.d._b)
[X] (Greenwheels, n.d.)
[Y] (emio-sharing, n.d.)
[Z] (nextbike GmbH, n.d.)

a) Median after tax income per month
b) Always the suggested fares, yearly kilometers traveled, and the smallest engine were chosen and no additional costs were included.
c) The minimum parking fare vary according to the time of day.
d) when travelling at a speed greater than 20.24 kilometers per hour.
e) Opposed to taxi fares the minute fare is charged based on the complete trip length and not only when the car is waiting.
f) If the applicable charge is smaller than the minimum charge the minimum charge is charged instead.
g) The fare is subject to surcharges if the demand is high but the number of available drivers is low.
h) The fares are simplified in this table.
i) Opposed to other forms of vehicle sharing only the cheapest fare of both fares (per minute or per km) is charged

Household spending

The percentage of income spent on food and shelter is very similar between Berlin and Calgary. However, the share that residents spend on transportation in Berlin is nearly half that of Calgary, 11.5 % and 19.5 %, respectively (Statistics Canada, 2010) (Amt für Statistik Berlin-Brandenburg, 2016 pp. 26-27). Residents in Berlin spend more than twice the share of their income on free time activities, hotels, and restaurants, when compared to residents in Calgary (Statistics Canada, 2010) (Amt für Statistik Berlin-Brandenburg, 2016 pp. 26-27).

Table 2-8: Average household expenditures

	Berlin	Calgary
Food	12.6 %	13.6 %
Shelter	26.8 %	27.6 %
Household operation	6.3 %	6.5 %
Household furnishings and equipment	5.0 %	3.5 %
Clothing	5.0 %	6.4%
Transportation	11.5 %	19.0 %
Health care	-	3.6 %
Personal care	3.8 %	2.4 %
Recreation and Reading materials	12.5 %	8.4 %
Education	1.0 %	2.8 %
Tobacco products and alcoholic beverages	1.8 %	3.3 %
Games of chance (net amount)	-	0.8 %
Miscellaneous	4.3 %	2.0 %
Post and telecommunication	3.2 %	-
Restaurants and Hotels	6.2 %	-

Source: (Statistics Canada, 2010) (Amt für Statistik Berlin-Brandenburg, 2016 pp. 26-27)

3. METHODS

3.1 Data Acquisition and Description

3.1.1 Data Setup

The study builds on a data set about free-floating carsharing service in Berlin and Calgary. The focus of this analysis relies on the time between August 1, 9:06 pm CET 2016 and November 30, 11:57 pm CET, 2016. Unfortunately, data from DriveNow in Berlin is only available for the months of August and September. Every three minutes information about all available vehicles was downloaded from the respective webpages of car2go and DriveNow. If a vehicle is not available, it is presumed that the vehicle is either rented or reserved by a customer or employee. Based on the unavailability of cars, a data set was created where the begin of a rental is the time the car was not listed as available on the webpage anymore and the endpoint of the rental is the time the car was available for customers again. The data set includes the following information:

Table 3-1: Information included in the data set about the usage of free-floating carsharing

Variable	Description
ID	Identification of the rental
TIMESTAMPSTART	Time and day of the booking
TIMESTAMPEND	Time and day of the end of the rental
PROVIDER	Provider of the carsharing vehicle
VEHICLEID	Identification number of the vehicle
LICENCEPLATE	License plate number
MODEL	Model specification of the car
INNERCLEANLINESS	The cleanliness of car interior, assessed by the renter
OUTERCLEANLINESS	The cleanliness of the outside of the car, assessed by the renter
FUELTYPE	Fuel type including elective drive
FUELSTATESTART	Filling level at the time of the reservation
FUELSTATEEND	Filling level at the end of the rent
CHARGINGONSTART	State of charge at the time the reservation
CHARGINGONEND	State of charge at the time the reservation
STREETSTART	Address of the car at the time of the reservation
STREETEND	Address of the car at the end of the reservation
LATITUDESTART	Latitude coordinates of the position of the car at the time of the reservation
LONGITUDESTART	Longitude coordinates of the position of the car at the time of the reservation
LATITUDEEND	Latitude coordinates of the position of the car at end of the rent
LONGITUDEEND	Longitude coordinates of the position of the car at end of the rent

3.1.2 Data cleaning

The aim was to delete as few rentals as possible; if a rental is deleted, the end point of a previous rental is no longer the start point of the next rental which results in incongruities in spatial analysis of the trip departure and arrival points. Thus, only rentals that do not obey the law of physics (e.g. traveling faster than 180 km/h within the home area) or the terms and conditions (e.g. exceeding the maximum rental period) of the respective free-floating carsharing provider are deleted. Rentals were included regardless of whether they follow the common sense or obeyed traffic regulations. Removing these erroneous records had little effect on the overall data set. The total number of recorded rentals in Berlin (1,120,949) and Calgary (369,699) was reduced by 0.31 %.

3.1.3 Limitations

Given that the data was downloaded from a webpage, it is possible that the data includes incorrect or missing values. If the download from the webpage is incomplete and data about a few vehicles is missing, it would be presumed that these vehicles are rented even though they are not rented. The travel distance is measured as the direct-line distance between the start point of the rental and the endpoint. Consequently, the street network based distance is higher. In Germany 1.24 is a commonly used detour factor for trips shorter than 100 km (Berens, et al., 1983 p. 70). Since nothing is known about intermediate stops, the travel distance of roundtrips is underestimated. Given that the data is downloaded only every three minutes, it could be the case that the rental period has started and ended up to three minutes earlier than noted. Further, it is not possible to calculate the exact duration of the rental period because only the total of reservation and rental time is known. In other words, only the duration a car is not available to another customer due to being rented or reserved and the idle duration of a car (waiting for a customer) is known. However, it is also possible that an entire trip was not completed by a customer but instead was a relocation drive by employees. For all these reasons, it is not possible to calculate the exact average speed, the exact duration of the rental period, and the fare for the trip. Even if the exact rental duration would be known, the calculation of the exact charge is not possible in Berlin due to special prepaid packages and reduced fares while the car is waiting.

The data from Berlin and Calgary is recorded in “Central European Time”. However, in this report the time of rentals in Calgary is converted into the local time in Calgary. The daylight-saving time ended in Germany on the October 30, 2016 (WeltN24 GmbH, 2016) and in Calgary one week later (Time and Date AS, n.d.). This was considered to be irrelevant in the analysis and Calgary was assumed to have always been 8 h behind Germany.

3.2 Analysis

The analysis was performed by using PostgreSQL Version 1.22.1, QGIS Version 2.14.3, RStudio 3.3.2 and Excel 2016. The code of the database queries can be found in the Appendix.

4. RESULTS

4.1 Exploratory analysis

This chapter compares the travel distance, reservation/rental time and the mean speed in Berlin and Calgary based on the mean, standard deviation, quantiles and a Wilcoxon sign test. Unlike the travel distance and mean speed, it is possible to calculate the mode of the travel/reservation time as it is a discrete variable because of the way the data is collected. Given that the data are not normally distributed and have outlines, it is not advisable to perform a t-test even though the number of observed cases (rentals) is rather high. Owing to this issue, the median clearly represents the data better than the mean and was therefore chosen to compare the cities.

Table 4-1: Explorative analysis of the rentals in Berlin and Calgary

	Berlin			Calgary		
	Distance [m]	Travel/ reservation time [min]	Mean speed [km/h]	Distance [m]	Travel/ reservation time [min]	Mean speed [km/h]
Mean	4353.5	51.7	8.0	2683.6	41.9	6.7
Standard deviation	3518.5	123.3	7.1	2294.1	130.2	6.4
Mode	-	27	-	-	15	-
10th percentile	798.9	15	1.2	292.6	9	0.9
First quartile (Q1) (25th percentile)	1840.1	21	3.9	1061.1	15	3.0
Median (50th percentile)	3597.9	33	7.0	2111.1	24	5.4
Third quartile (Q3) (75th percentile)	5978.4	48	10.7	3827.0	39	8.8
90th percentile	8763.6	72	14.8	5553.1	57	13.2

Source: Authors' analysis of data provided by TU Dresden

4.1.1 Distance

The median of the direct-line distance between the departure and arrival point is approximately one-third shorter in Calgary than in Berlin. This is supported by a Wilcoxon sign test, which indicates a significant difference between the distance traveled per rental in Berlin and Calgary, $W = 2.7025e+11$, $p < 0.001$. Notably is that in Calgary the percentage of rentals that are shorter than 200 m is twice as high as in Berlin.

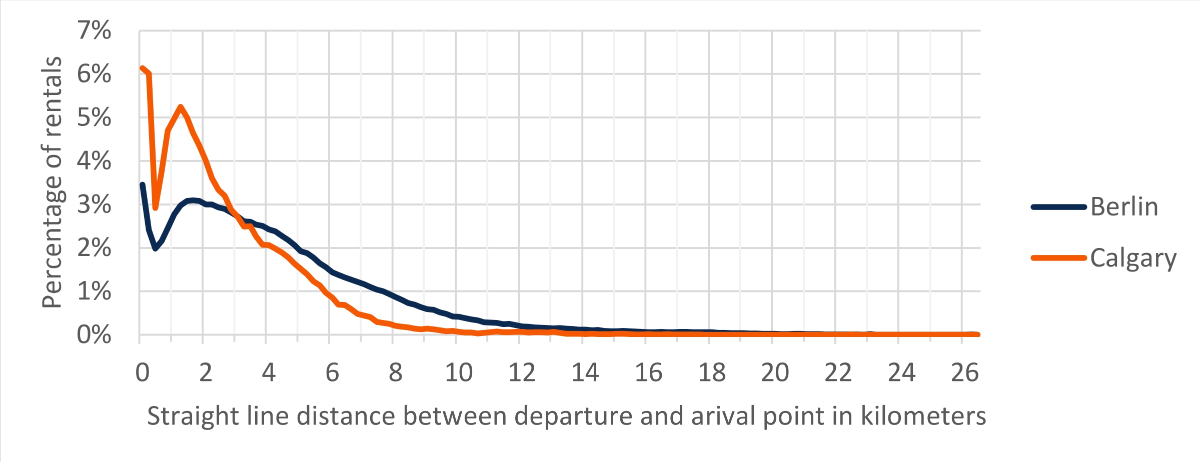

Figure 4-1: Straight line distance traveled per rental [200 m bin width]
Source: Authors' analysis of data provided by TU Dresden

4.1.2 Reservation/rental time

Similar to the travel distance, the median of the reservation/rental time in Berlin is about one-third longer than in Calgary. At 0.05 significance level, a Wilcoxon Rank-Sum Test showed that the reservation/rental time in Berlin was longer than in Calgary, W = 2.5651e+11, $p < 0.001$. It is striking that Calgary has a large number of rentals that are 3 minutes long, which is not the case in Berlin.

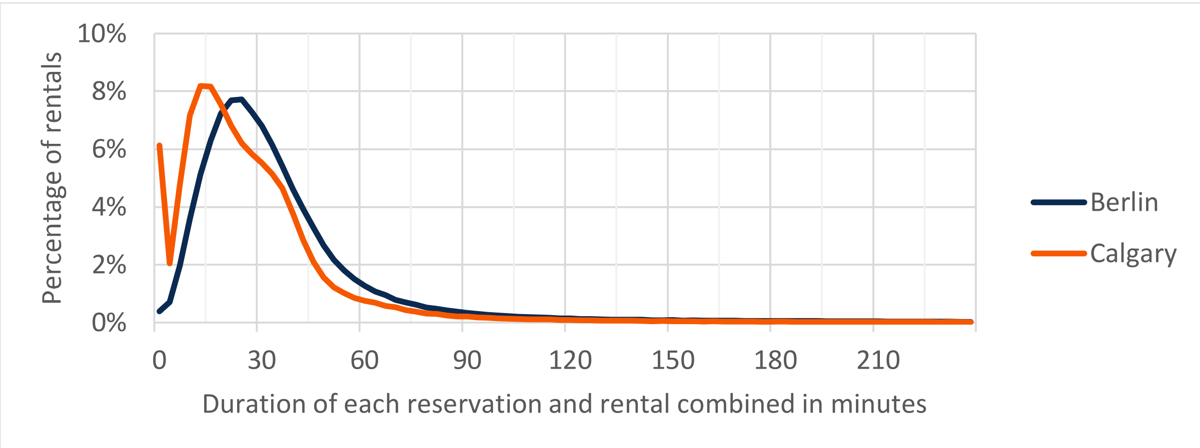

Figure 4-2: Duration of each reservation and rental combined [3 minutes bin width]
Source: Authors' analysis of data provided by TU Dresden.

4.1.3 Average speed

A Wilcoxon Rank-Sum Test implies that the average speed in Berlin was higher than for rentals in Calgary, W = 2.38e+11, $p < 0.001$.

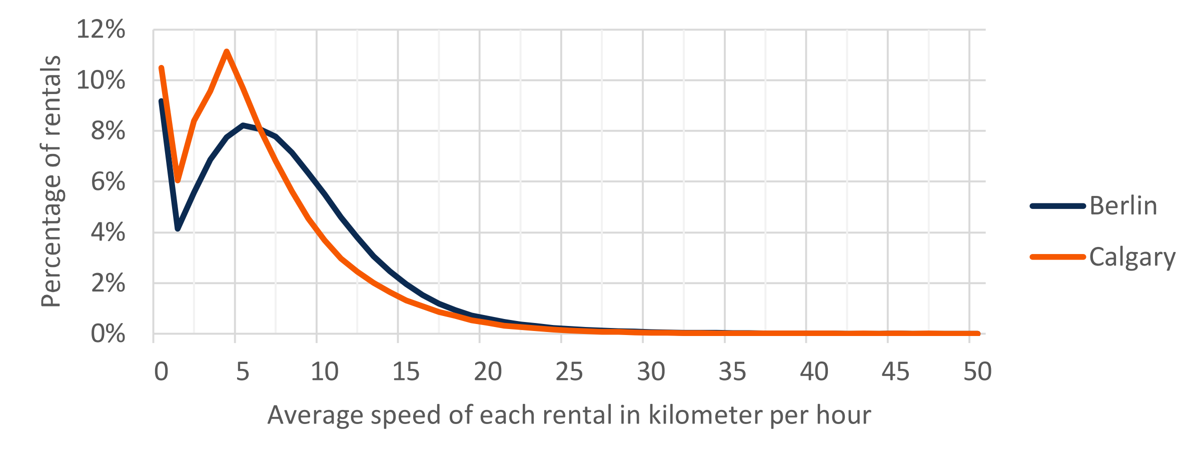

Figure 4-3: Average speed of each rental [1 km/h bin width]
Source: Authors' analysis of data provided by TU Dresden.

4.1.4 Carsharing bookings in the course of a day

Comparing **Figure 4-4** and **Figure 4-5** to **Appendix 1.5** it can be seen that the graph of the carsharing bookings in Berlin on weekdays is similar to the traditional two-humped urban commute pattern, whereas the rentals in Calgary follow the single-hump pattern commonly seen in rural areas. Admittedly, the three peaks on the single-hump of the carsharing bookings graph in Calgary are more distinct than in the traffic volume graph in rural areas. Worth noting is that the downtown car traffic in Calgary follows the traditional two-humped urban commute pattern. Another abnormality is the small daily peak at 2 am of car2go bookings in Calgary, which cannot be seen in any other traffic pattern. In contrast to the public transport usage and vehicle travel of people living within the Berlin Ringbahn, the morning and evening humps of the carsharing bookings graph in Berlin are flatter. The number of carsharing bookings in both cities decreases only gradually after 6 pm and stays relatively high throughout the night, as opposed to car traffic which declines quickly and stays low at night.

Overall, the carsharing usage on weekends in both cities has a similar trend to the car traffic volume on weekends apart from the striking evening peak of the number of carsharing bookings on Saturdays, which is even more distinct in Calgary than in Berlin.

Table 4-2: Percentage of carsharing bookings per day

Weekday	Berlin %	Calgary %
Monday	13.0%	12.8%
Tuesday	14.3%	15.1%
Wednesday	14.4%	14.8%
Thursday	14.1%	15.8%
Friday	15.4%	18.3%
Saturday	15.6%	13.6%
Sunday	13.2%	9.7%

Source: Authors' analysis of data provided by TU Dresden.

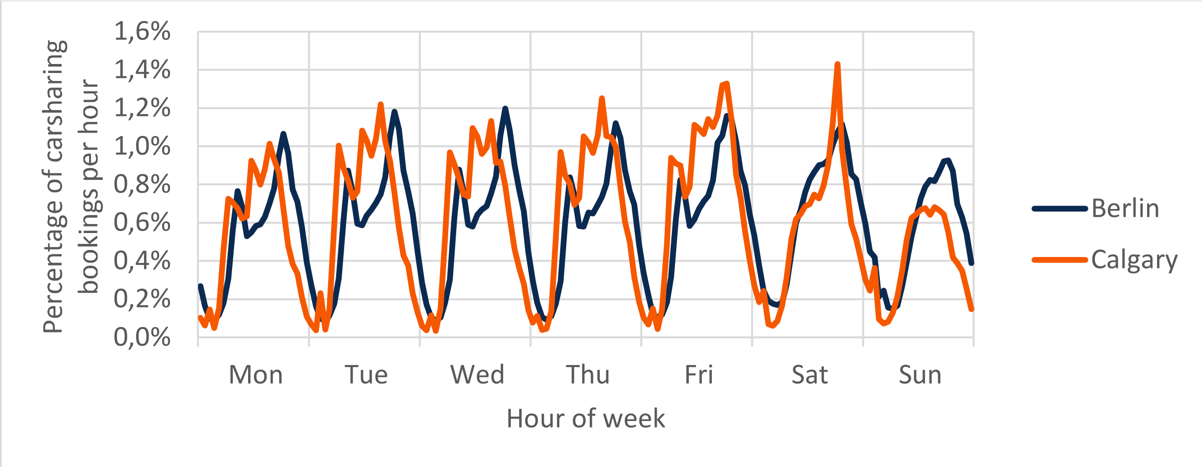

Figure 4-4: Average number of free-floating carsharing bookings over the week in Berlin and Calgary
Source: Authors' analysis of data provided by TU Dresden.

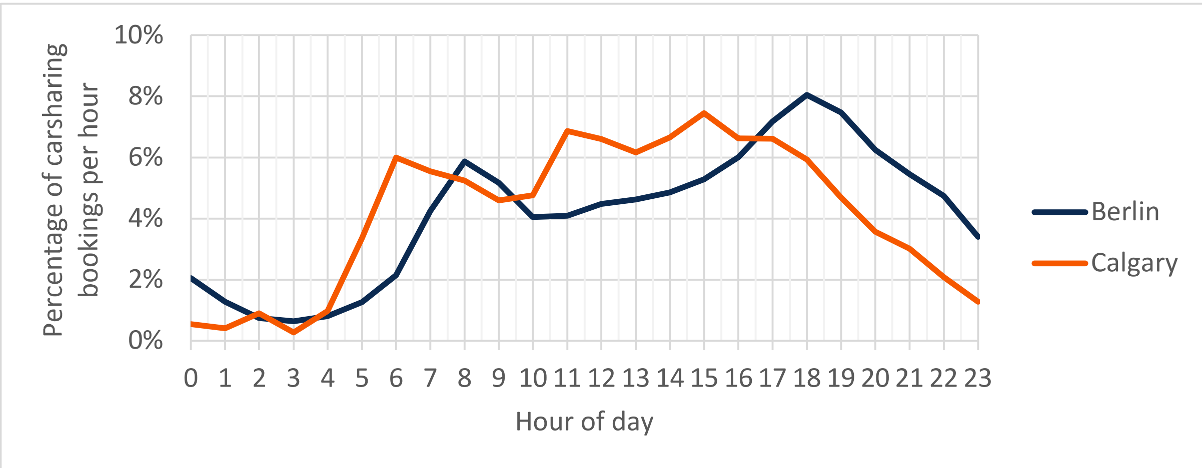

Figure 4-5: Average number of free-floating carsharing bookings on weekdays in Berlin and Calgary
Source: Authors' analysis of data provided by TU Dresden.

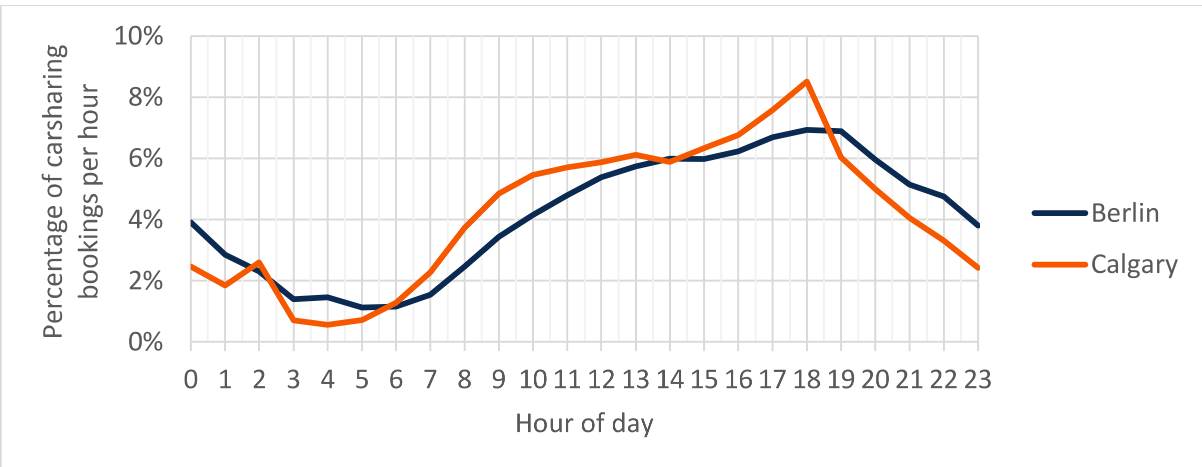

Figure 4-6: Average number of free-floating carsharing bookings on weekends in Berlin and Calgary
Source: Authors' analysis of data provided by TU Dresden.

4.2 Spatial analysis

4.2.1 Spatial distribution of departures and arrivals

As presented in **Appendix 1.2**, the geographic concentration of arrivals in Berlin is in Berlin Mitte, Friedrichshain and Prenzlauer Berg. Additional scattered hotspots of arrivals occur near the Berlin Tegel Airport and Berlin Schoenefeld Airport. Over the course of day, the geographic concentration of departures and arrivals stays relatively constant except between 6 am and 9 am, where fewer rentals start in Berlin Mitte than in the surrounding neighborhoods and most rentals end during this period in Berlin Mitte.

The spatial distribution of arrivals in Calgary focuses mainly on the downtown area and the surrounding neighborhoods with a few scattered hotspots in the northern part of the home area. From 6 am to 12 pm, a high percentage of rentals end in the downtown area and near the University of Calgary. During the rest of the day, the arrivals are slightly more evenly distributed among the hexagons even though rentals clearly end predominantly in the downtown area. From 9 am until 6 pm most rentals start in the downtown area of Calgary and the surrounding hexagons. In the morning as well as in the evening a considerable number of rentals also depart from other neighborhoods.

In **Table 4-3** the hexagons are grouped by the number of arrivals per day. The number of arrivals per day per hexagon is relatively similar in both cities. The only difference is hexagon 504, which is in the center of Calgary's downtown. On average 501 cars arrive in this hexagon per day, which accounts for 17.8 % of all arrivals including round trips from and to hexagon 504, as displayed in **Table 4-4**. The roundtrips to and from hexagon 504 account for 5.0 % of all trips. If round trips from and to hexagon 504 are excluded, 25.6 % of all trips in Calgary connect hexagon 504, with other hexagons in Calgary. If the surrounding hexagons are included, these numbers are even higher. In fact, 71.2 % of all rentals start or end in the downtown, near the Calgary International Airport, or near the University of Calgary.

Table 4-3: Distribution of arrivals among the hexagons

Number of Hexagons were…	Berlin		Calgary	
	number	%	number	%
…more than 500 cars arrive per day	0	0.0 %	1	0.8 %
…between 400 and 500 cars arrive per day	0	0.0 %	0	0.0 %
…between 300 and 400 cars arrive per day	0	0.0 %	0	0.0 %
…between 200 and 300 cars arrive per day	1	0.3 %	2	1.6 %
…between 100 and 200 cars arrive per day	19	6.3 %	3	2.4 %
…between 80 and 100 cars arrive per day	12	4.0 %	1	0.8 %
…between 60 and 80 cars arrive per day	22	7.3 %	2	1.6 %
…between 40 and 60 cars arrive per day	29	9.6 %	6	4.8 %
…between 20 and 40 cars arrive per day	57	18.9 %	14	11.1 %
…between 1 and 20 cars arrive per day	102	33.9 %	78	61.9 %
…between 1 car arrives within 4 month and 1 car arrives per day	59	19.6 %	19	15.1 %
Sum	301	100 %	126	100 %

Source: Authors' analysis of data provided by TU Dresden.

Table 4-4: Trips to and from downtown Calgary

	Calgary	
	number	%
Rentals that neither depart nor arrive in Hexagon 504	255614	69.4%
Rentals that depart and arrive in Hexagon 504 (round trips)	18591	5.0%
Rentals that depart and not arrive in Hexagon 504	47094	12.8%
Rentals that arrive and not depart in Hexagon 504	47111	12,8%
Sum	368544	100.0%
Rentals that start or end in one of the seven downtown hexagons	243544	66.1%
Rentals that neither start nor end in one of the seven downtown hexagons	124887	33.9%
Sum	368544	100.0%

Source: Authors' analysis of data provided by TU Dresden.

4.2.2 Frequency of rentals with a similar start and end point

As displayed in **Table 4-5:** Frequency of similar rentals, it is rare that a trip between two specific hexagons is made more than twice per day. In contrast to Berlin, Calgary has one connection (the previously mentioned roundtrip to and from hexagon 504) which is driven on average 152 times per day, accounting for 5.0 % of all trips.

Table 4-5: Frequency of similar rentals

Number of connections between two hexagons that are driven…	Berlin		Calgary	
	number	%	number	%
…more than 150 times per day	0	0.0 %	1	< 0.1 %
…between 100 and 150 times per day	0	0.0 %	0	0.0 %
…between 50 and 100 times per day	0	0.0 %	0	0.0 %
…between 10 and 50 times per day	5	0.0 %	33	0.4 %
…between 5 and 10 times per day	46	0.1 %	48	0.5 %
…between 4 and 5 times per day	42	0.1 %	29	0.3 %
…between 3 and 4 times per day	111	0.2 %	41	0.4 %
…between 2 and 3 times per day	313	0.7 %	99	1.1 %
…between 1 and 2 times per day	1338	2.9 %	282	3.0 %
…between 1 time within 4 month and 1 time per day	44562	96.0 %	8767	94.3 %

Source: Authors' analysis of data provided by TU Dresden.

5. POSSIBLE REASONS FOR THE DIFFERENCES IN THE FREE-FLOATING USAGE

The explanation presented in this chapter are with a few exceptions purely based on economic dimensions. It goes without saying that there could be additional, and possibly better, explanation if other dimensions would have been included, such as for example the availability of vehicles.

5.1 Fewer rentals, fewer members and fewer cars in Calgary

As illustrated in chapter 2, Calgary is generally speaking less supportive of carsharing than Berlin. First, the population density in Berlin is almost 3 times as high as in Calgary. Second, the residents in Berlin are more likely to use carsharing given that they have fewer cars per household, a lower mode share for cars, a higher percentage of people who live alone or with one other person and a higher level of education. Only based on the age distribution and unemployment rate, is Calgary more supportive of carsharing than Berlin. In sum, Berlin has more people per square kilometer and these people live in arrangements, which increase their likeliness of becoming a carsharing member when compared with residents in Calgary. Additionally, the most-sold car in Canada (Ford F-Series) costs the same to operate per month as doing 30.6 times a 10-km trip with car2go. In Berlin, 88.0 10-km trips cost the same as operating the most-sold car in Germany per month (Volkswagen Golf). On these grounds, it seems to be obvious why Calgary has fewer car2go members and cars than car2go in Berlin or DriveNow in Berlin.

5.2 Travel distance

The fact that the travel distance is shorter in Calgary than in Berlin may seem surprising given that the median commuting distance to work is 7.7 km in Calgary (Statistics Canada, 2009) and the mean travel distance is 6.0 km in Berlin (Ahrens, et al., 2015 p. Tab 3). However, various arguments can be put forward to explain why the mean travel distance is longer in Berlin than in Calgary. The most obvious explanation is that the home area of both DriveNow and car2go in Berlin is twice the size of the home area of car2go in Calgary. Hence the distance from the center of the home area to the edge is about 7 km in Berlin and 5 km in Calgary. The fact that 83.3 % of trips are shorter than 7 km in Berlin and similarly 87.3 % of trips are shorter than 5 km in Calgary somewhat supports the assumption that there might be a connection between the radius of the home area and the distance traveled. As presented in **Table 4-4** 66.1 % of carsharing trips in Calgary either connect the downtown area to the surrounding areas or are roundtrips within the downtown area. In this respect, most trips in Calgary should be shorter than the distance from downtown to the edge of the home area.

5.3 Reservation/rental duration

The most likely explanation for the longer median rental/reservation duration in Berlin compared to Calgary is that the median travel distance in Berlin is also longer.

5.4 Geographic distribution of departures and arrivals

A major difference between the carsharing usage in Berlin and Calgary is that most trips in Calgary start or end in downtown, which is not the case in Berlin. This may be predictable given the city structure of Calgary. An additional reason could be the high parking prices. Calgary has, according to the global real estate firm Colliers International's 12th Annual Parking Survey, the second highest monthly parking fees in North America; only New York City is more expensive (Colliers International Canada , 2012). As a consequence, it could be cheaper, especially at day time when the hourly parking fee is enforced, to drive a car2go car to the downtown instead of one's own car. The average round trip to the downtown costs approximately \$ 8 to \$ 12[3] which is in most cases cheaper than paying a day or hourly parking ticket as can be seen in **Table 2-7**. The median rate for a monthly unreserved parking spot is \$ 456.75 in Calgary (Colliers International Canada , 2012), which is the same price as between 38 and 57 round trips to downtown. It may not only be less expensive to use car2go instead of driving one's own vehicle for trips to the downtown, it should also be easier to find a parking spot because car2go vehicles can be parked in both to ParkPlus zones and residential permit areas (Markusoff, 2015). For all other trips, where no parking fees are enforced at the destination, using carsharing, as explained before, may be more expensive than owning a car. The hypothesis is in line with the study by Millar-Ball et al. (2005) who supports the assumption that parking pressure influences the success of carsharing (Millard-Ball, et al., 2005 p. 3).

5.5 Midnight peak of short carsharing bookings in Calgary

In contrast to Berlin, the number of carsharing bookings per hour has a small peak in Calgary between 1 am and 3 am. The most convincing reason for this phenomenon is that major bus routes finish at 12:20 am and the last C-Train departs at 12:30 am (TransCanada FoundLocally Inc., n.d). Thus, individuals may choose the second less expensive option to travel, namely car2go. In Berlin limited public transport service is available throughout the night (BerlinOnline Stadtportal GmbH & Co. KG, n.d._a). Hence, there is not a specific point in time from which on everybody is required to use an alternative mode of transport instead of public transport and therefore no peak is visible.

Another possible reason could be the high number of 3-minute-long trips. Between 2 am and 3 am, 67.2 % of all rentals are 3 minutes long while during the rest of the day this kind of rentals occur rarely. Based on the available data, it is hard to determine the reason for this phenomenon. It is possible that individuals tend not to reserve a vehicle at night. However, driving to a respective destination within 5:59 minutes is improbable. The fact that the travel distance is less than 243.4 m for 90 % of the short rentals at night, makes it questionable whether these bookings are bookings by customers. A possibility could be that car2go maintains the vehicles during the night and thus the vehicles are not available for a few minutes, which is recorded as bookings in the database. The employees may use the car2go vehicle

[3] Based on a 4-6 km trip in each direction

on which they just performed maintenance to drive a few hundred meters to the next vehicle. Another explanation is that these bookings could indicate a false reservation; individuals may book a vehicle and cancel the booking a few minutes later. GPS inaccuracies may cause the vehicles to seem to have moved for 10 m or less during approximately 75 % of these rentals.

5.6 Midday peak of carsharing booking in Calgary

The graph depicting the free-floating carsharing bookings on weekdays in Calgary has a peak between 10 am and 1 pm. This midday peak is assumed to be caused by short rentals used to run errands during lunch breaks by employees who work downtown. The number of rentals, which have a distance traveled of less than 200 m, is twice as high between 10 am and 1 pm when compared to the 3-hour time slice before and afterwards. These short rentals account for 9.1 % of all rentals during the peak, whereas in the 3 hours before and afterwards these rentals amount to 5.0 % and 7.0 %. People may choose car2go instead of their own vehicle because they would need to renew their parking lot ticket when they come back from their lunch break. Kortum et al. (2012) came to a similar conclusion in regards to the midday peak of car2go bookings in Austin (Kortum, et al., 2012 p. 54). The reduced public transport service during midday could also cause people to prefer car2go over public transport during lunch break. Berlin neither has the midday peak nor the short rentals.

5.7 Carsharing used to cover the last mile to access major public transport routes

According to a survey in Calgary, 25% of people who reported using public transport and carsharing stated that they use both together for a single trip (Duncan, 2014 p. 28). However, the assumption that people use carsharing to access major public transport routes instead of taking a bus cannot be concluded with certainty based on the available data. As can be seen in **Appendix 1.4** rentals start and end near C-Train stations. However, the number of arrivals is not considerably higher close to C-Train stations that are outside of downtown, than in areas without C-train stations. The same can be said about Berlin. There are hotspots of arrivals near a few light rail and underground stations but not next to all stations. Based on the available data it is also not possible to verify whether people take a bus to enter the car2go home area and continue their trip with a car2go vehicle.

6. CONCLUSION

6.1 Conclusion

The student project showed the difficulties in finding consistent success factors for carsharing. Even though Calgary scores poorly on most of the commonly known carsharing success factors, car2go membership is still high. One of the possible reasons for this is the high parking fees in downtown Calgary. Thus, free-floating carsharing, for trips to and from downtown, is the more economic option compared to driving one's own car and paying the parking fees. To run errands during lunch break in the downtown, taking a car2go vehicle could be less expensive than driving one's own car and reentering the parking lot especially those which have a maximum fare or those that charge per entry. Also during the night, when no public transport service is available, car2go bookings stay high.

However, it is questionable whether the kind of carsharing usage seen in Calgary, takes full advantage of the potential benefits of carsharing. It is likely that the demand for trips to the downtown, to the Calgary International Airport, or to the University of Calgary is high enough to incentivize the city of Calgary to provide good public transport services. Thus, it should not be the city planners' aim to have more than 70 % of all rentals start or end in the downtown or near the Calgary International Airport or near the University of Calgary.

In conclusion, high parking fees, and limited or no public transport during the night may be, under certain circumstances, a success factor for carsharing. Nevertheless, to take advantage of the possible benefits of carsharing, it is not enough to solely increase the parking fees in a few areas within the home area.

Based on the results of this study, it is advisable to investigate whether home area-wide parking fees and further increases in the variable cost of car driving could be options to support a free-floating carsharing system that provides the best possible advantages. It may be necessary to enforce parking fees in the entire city instead of solely in the home area, in order to reduce the number of trips, where individuals think that driving their own car could be less expensive.

6.2 Claim on generalizability and opportunities for related work

The generalizability of the findings is obviously limited given that only two cities have been analyzed. Hence, it would be advantageous to include further cities in the analysis to validate the factors that might affect the number of members in car-dependent, low-dense cities. Additionally, cities where free-floating carsharing went out of business should be analyzed to identify factors which inhibit the growth of this system. It is worth identifying not only factors that increase the likelihood that somebody becomes a member of a carsharing system, but also the factors which makes it possible that a carsharing system is used in a way that provides the highest possible benefits from a city perspective. Although the explanations for differences in carsharing usage seem reasonable, it could be advantageous to include other perspectives apart from economic ones, such as the attitude of the residents towards sustainability and so on. Another step would be to collaborate with car2go and analyze the profitability of the free-floating carsharing system in both cities.

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8. APPENDIX

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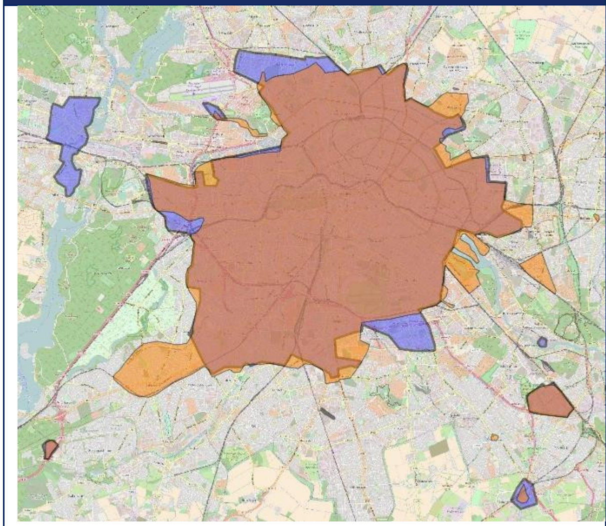
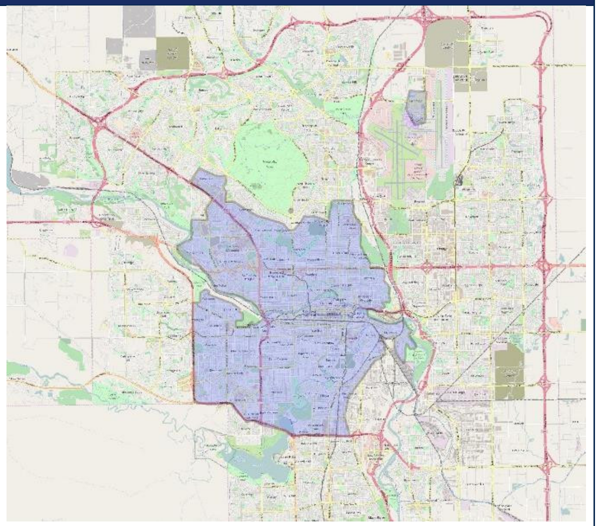
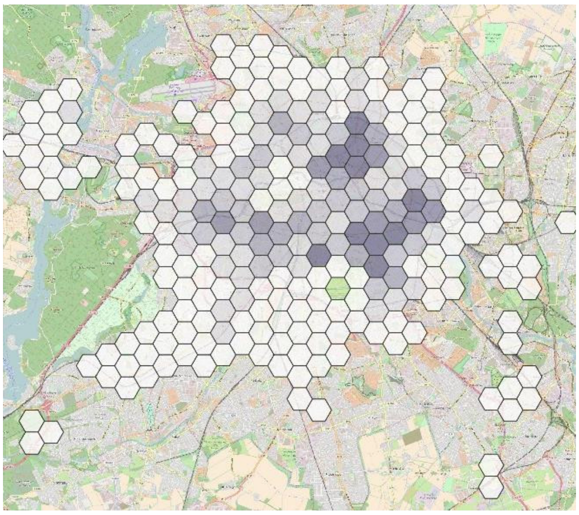
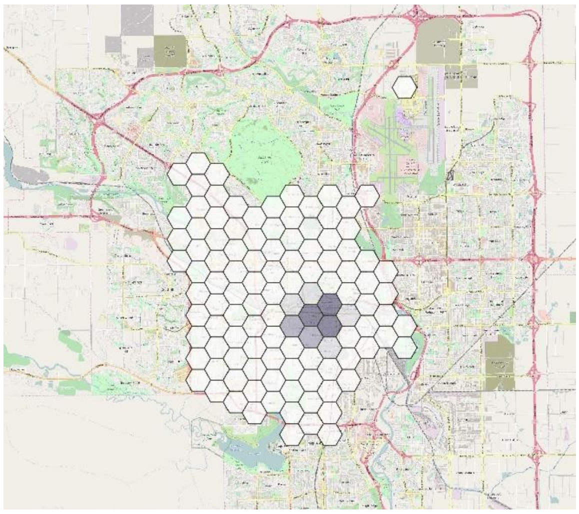
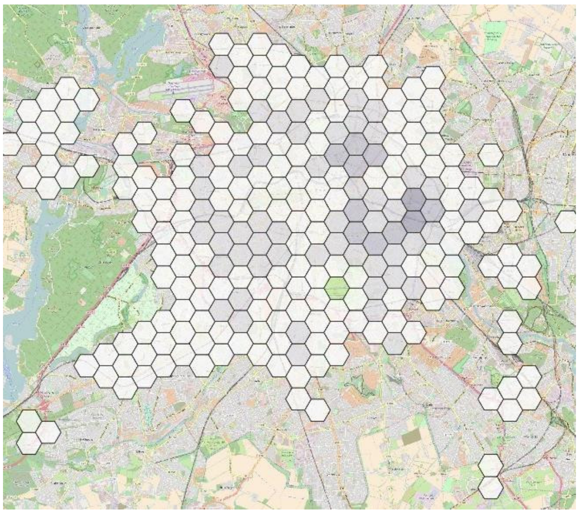
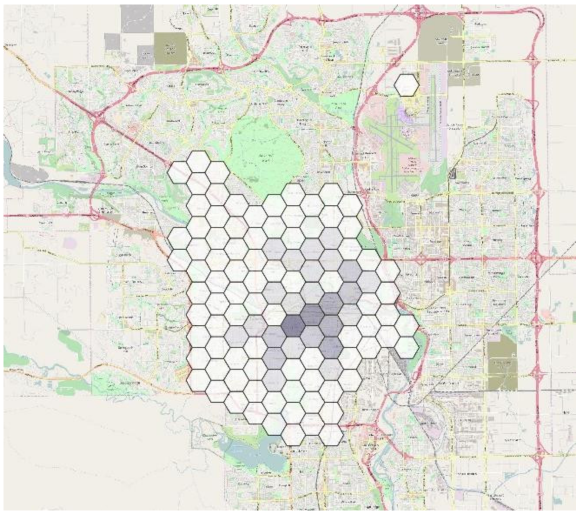
1. ADDITIONAL GRAPHICS

Appendix 1.1: Home area

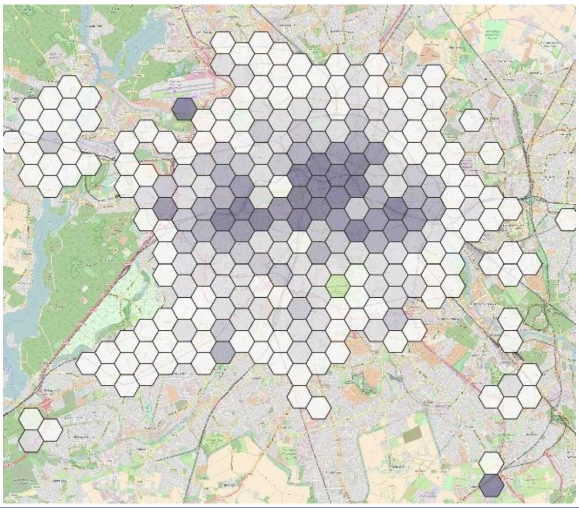
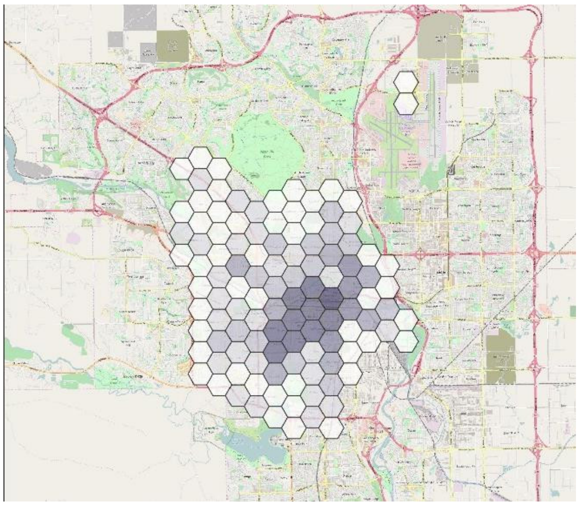
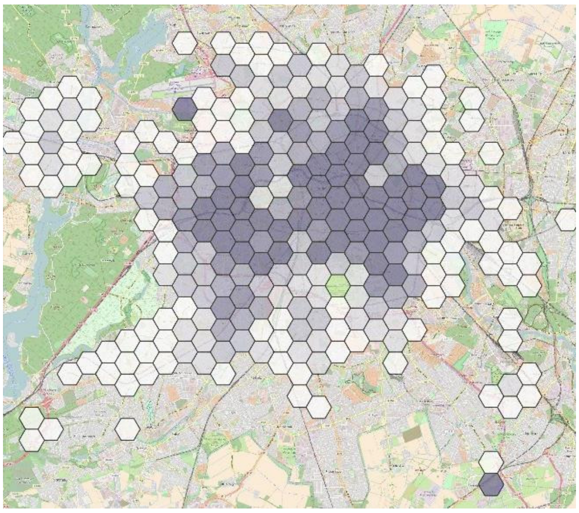
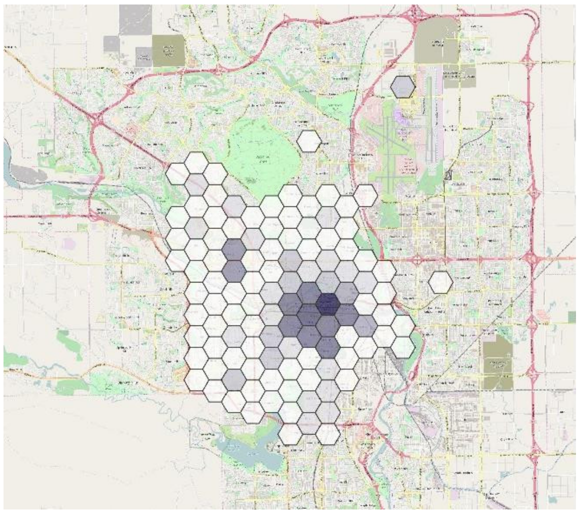
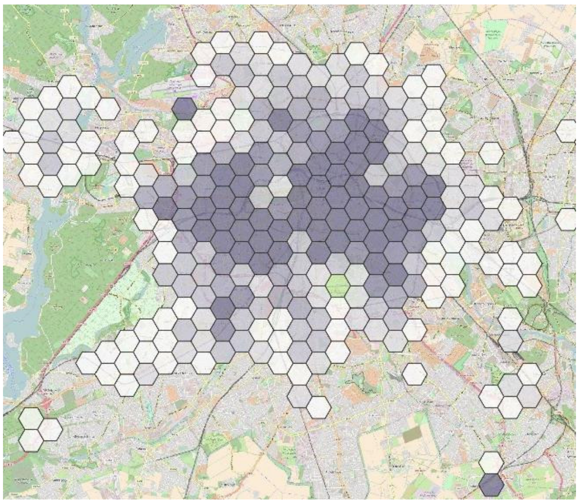
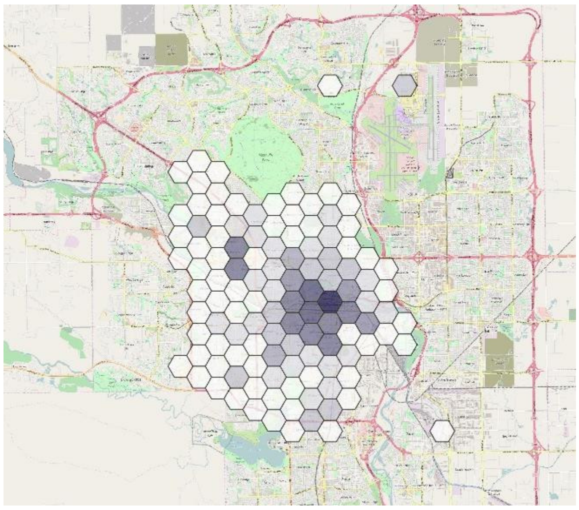
Berlin	Calgary
	
car2go home area DriveNow home area	

Appendix 1.2: Number of departures in each hexagon over the span of the day

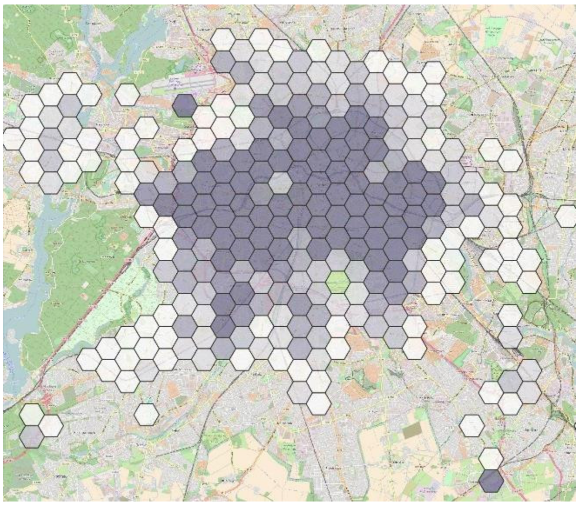
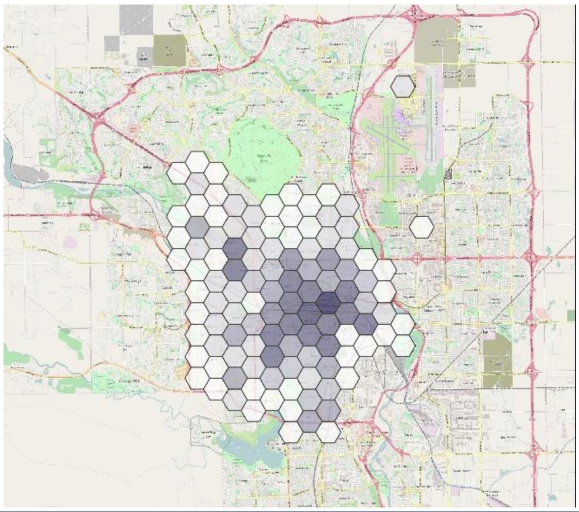
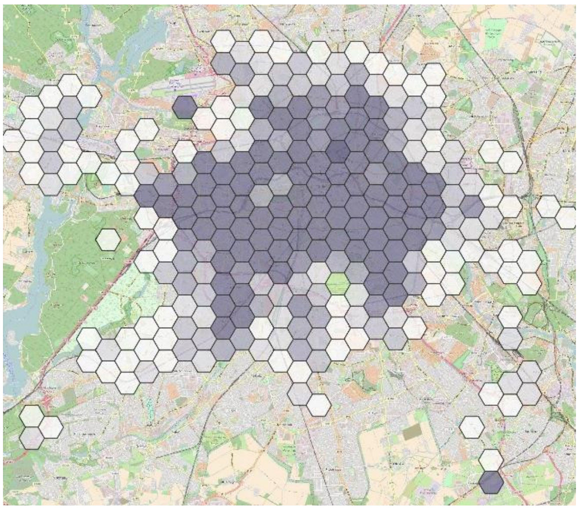
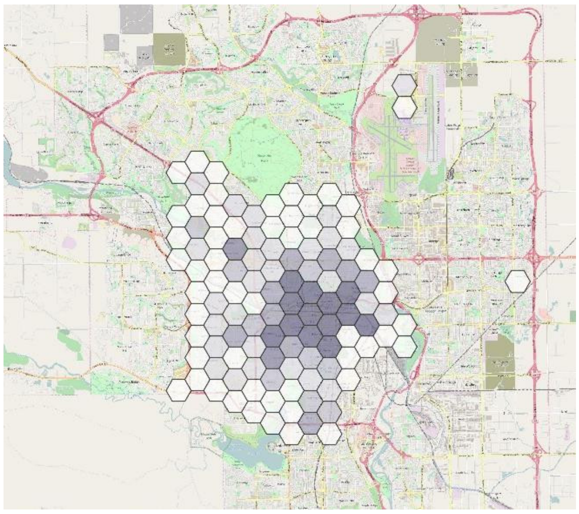
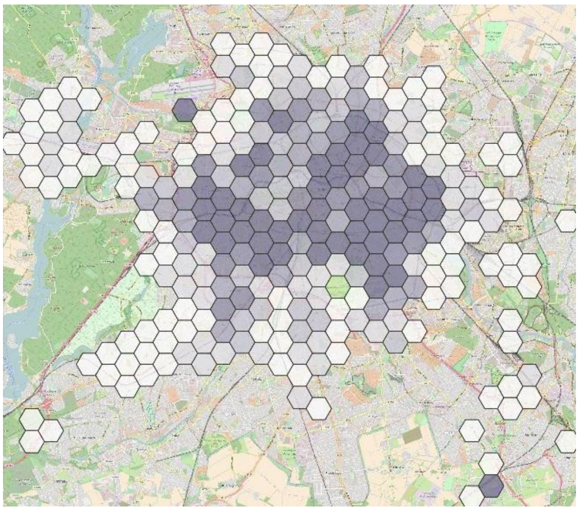
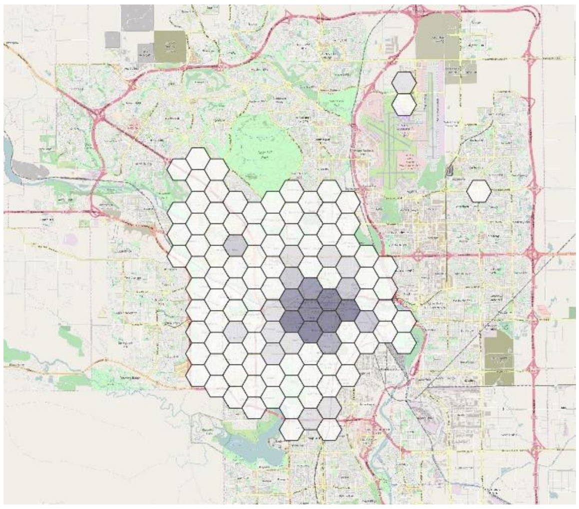
Sum of all departures in each Hexagon within two hours during the time of analysis (4 month)

Berlin	Calgary
Key – total number of departures per hexagon within 3 hours 1 - 200 200 - 400 400 - 600 600 - 800 800 - 1000 1000 - 5000 5000 - 10000 10000 - 15000 15000 - 20000 20000 - 25000	
00:00:00 – 03:00:00 	
03:00:00 – 06:00:00 	

Appendix 1.2 (continued)

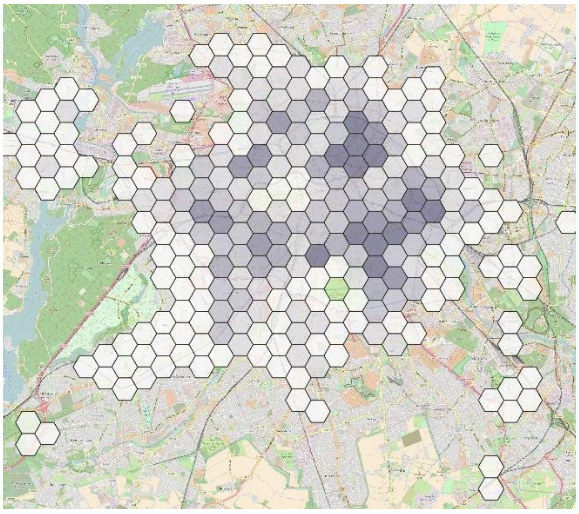
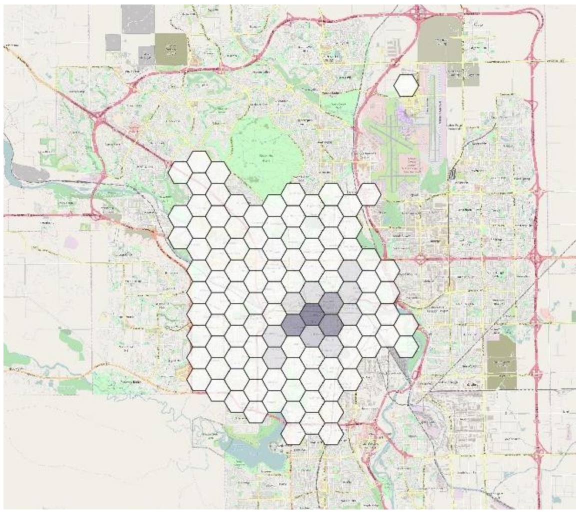
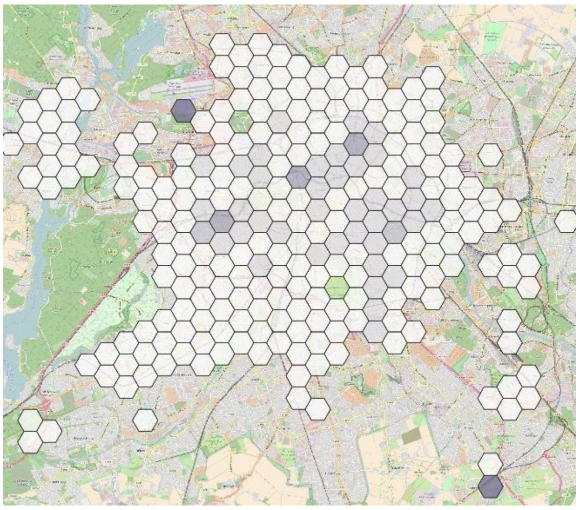
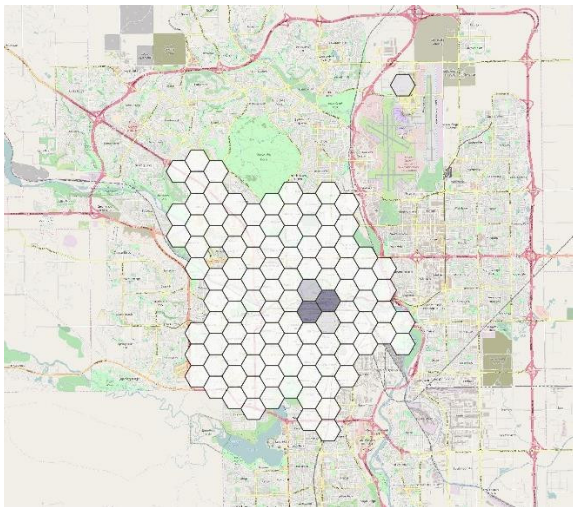
06:00:00 – 09:00:00 	
09:00:00 – 12:00:00 	
12:00:00 – 15:00:00 	

Appendix 1.2 (continued)

15:00:00 – 18:00:00 	
18:00:00 – 21:00:00 	
21:00:00 – 23:59:59 	

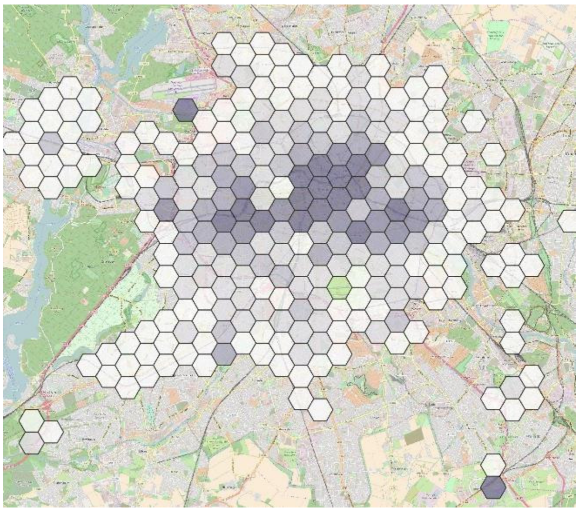
Appendix 1.3: Number of arrivals in each hexagon over the span of the day

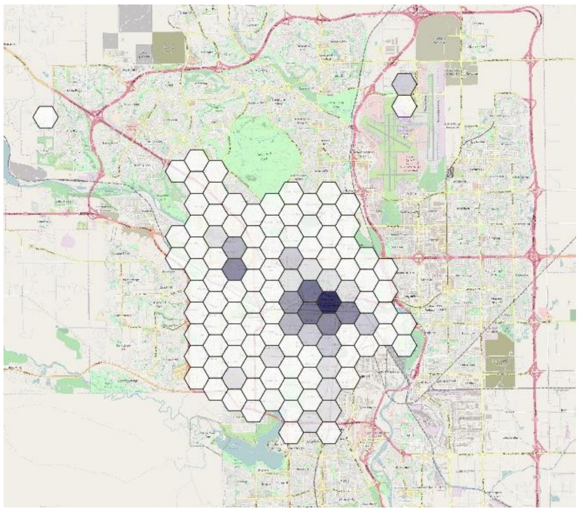
Sum of all arrivals in each Hexagon within two hours during the time of analysis (4 month)

Berlin	Calgary
Key – total number of arrivals per hexagon within 3 hours 1 - 200 200 - 400 400 - 600 600 - 800 800 - 1000 1000 - 5000 5000 - 10000 10000 - 15000 15000 - 20000 20000 - 25000	
00:00:00 – 03:00:00 	
03:00:00 – 06:00:00 	

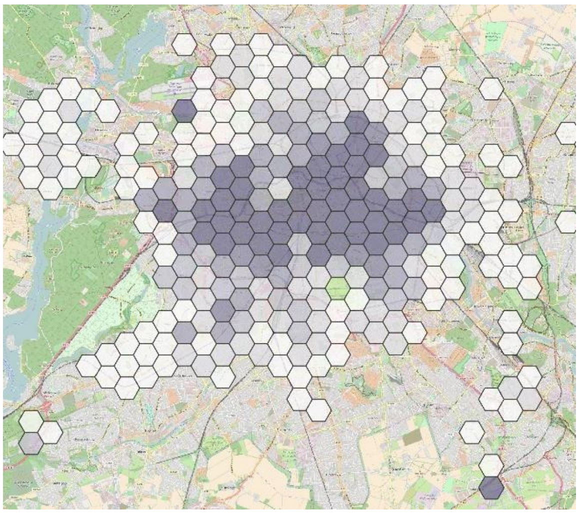
Appendix 1.3 (continued)

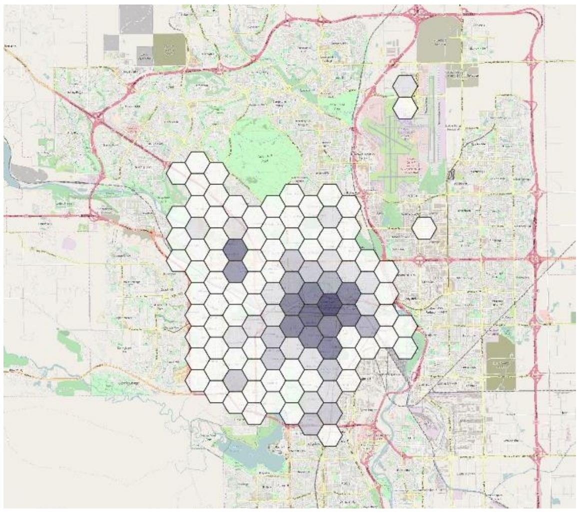
06:00:00 – 09:00:00



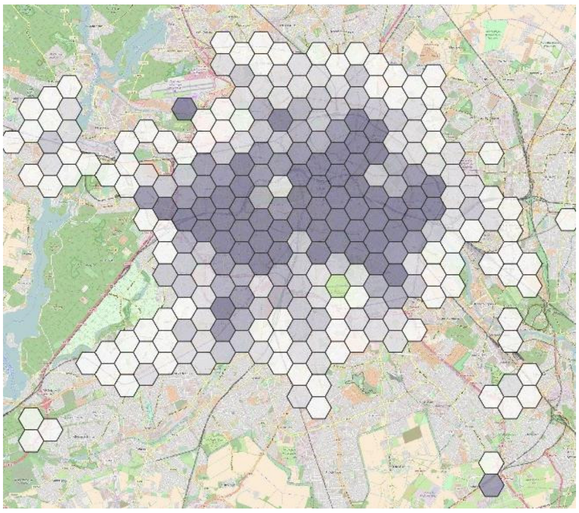


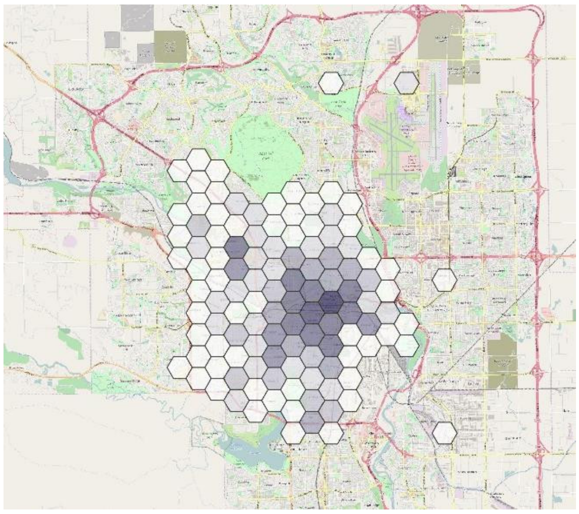
09:00:00 – 12:00:00



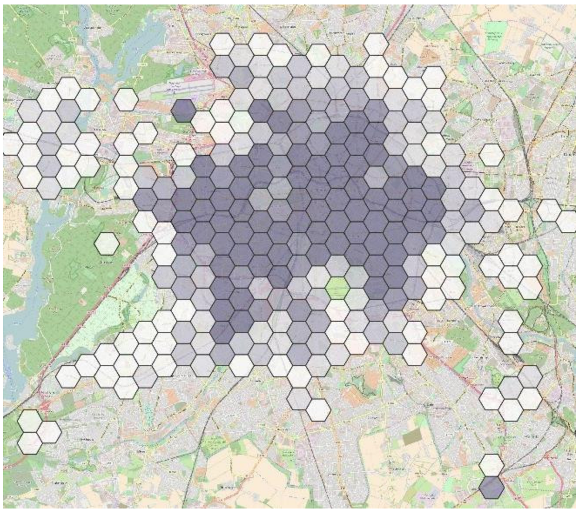
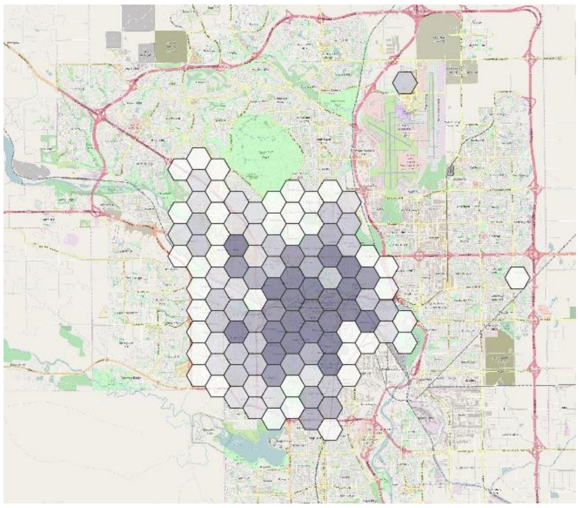
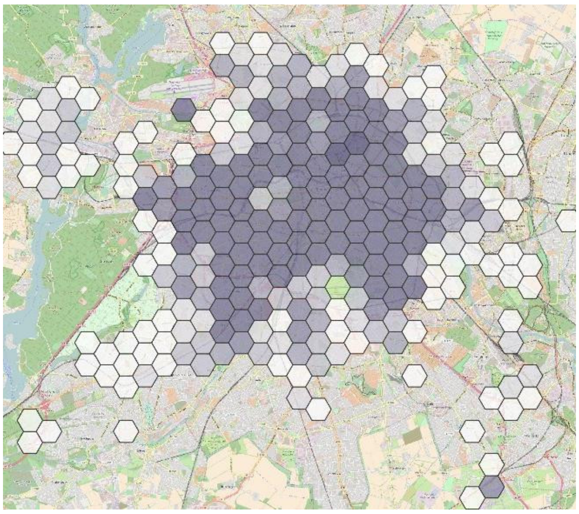
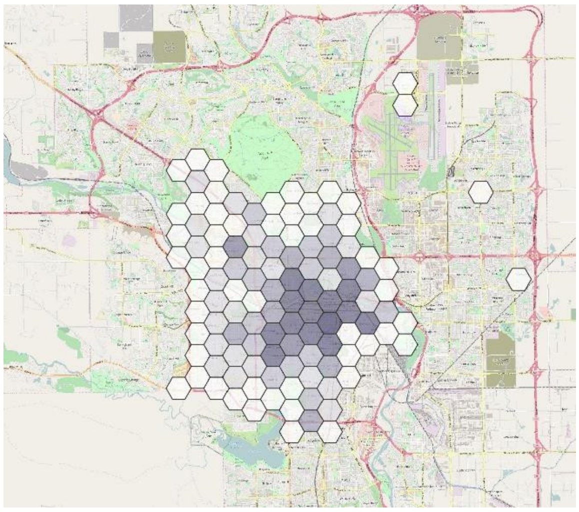
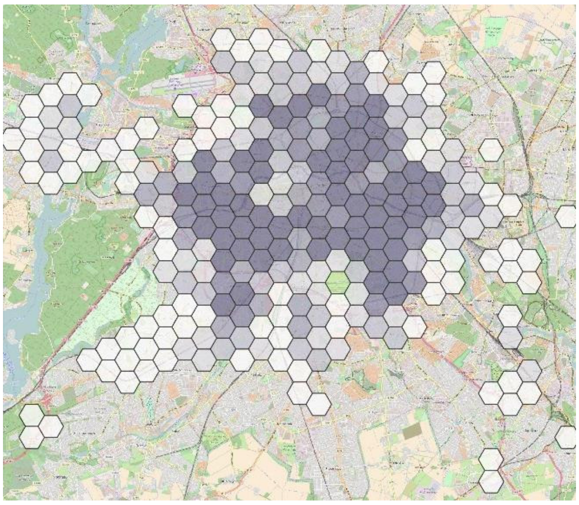
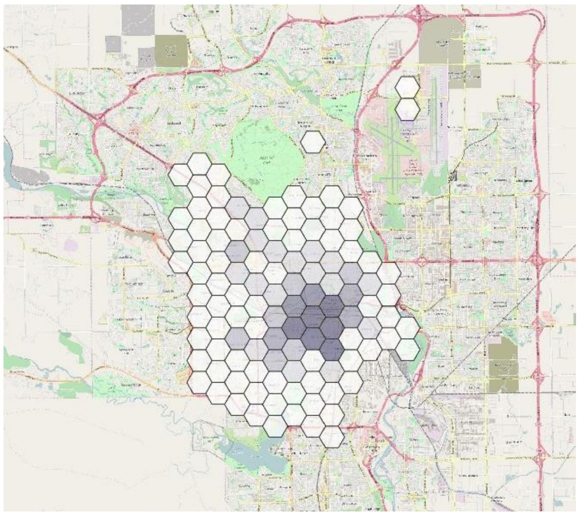


12:00:00 – 15:00:00

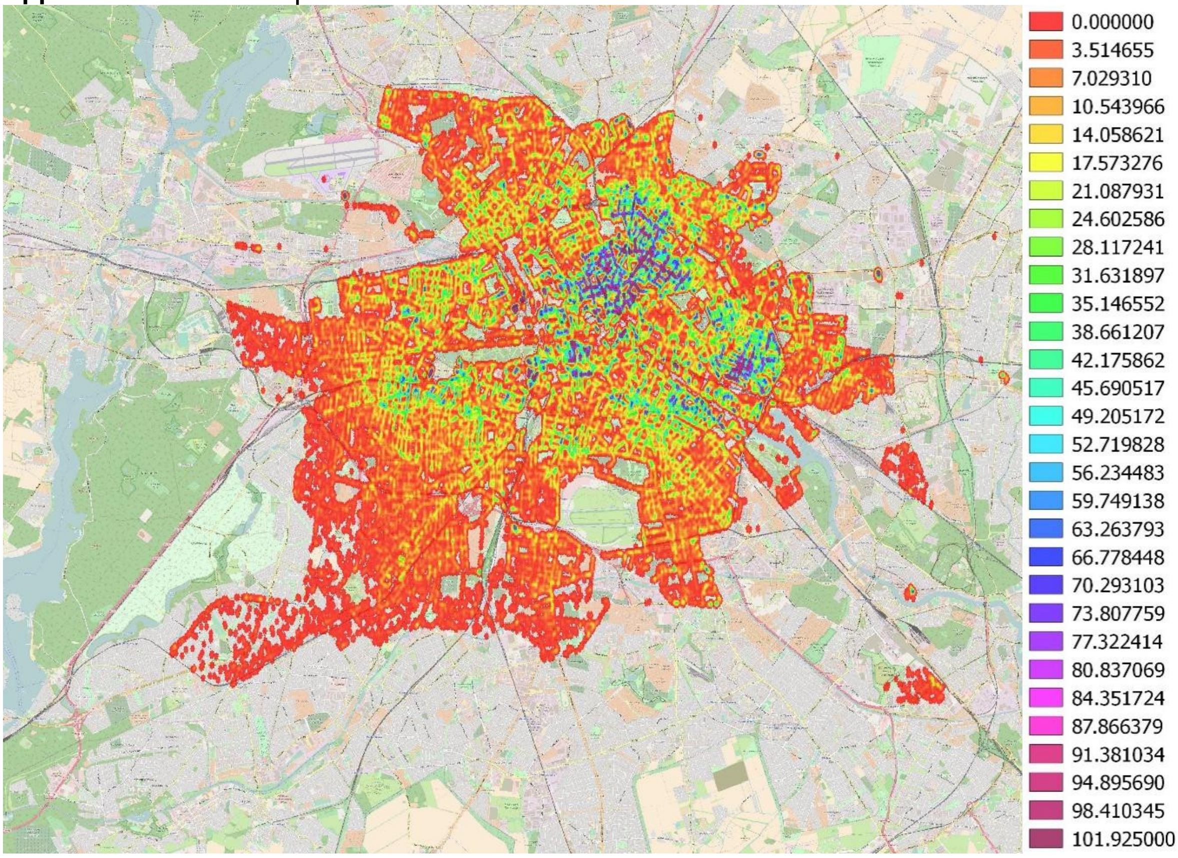




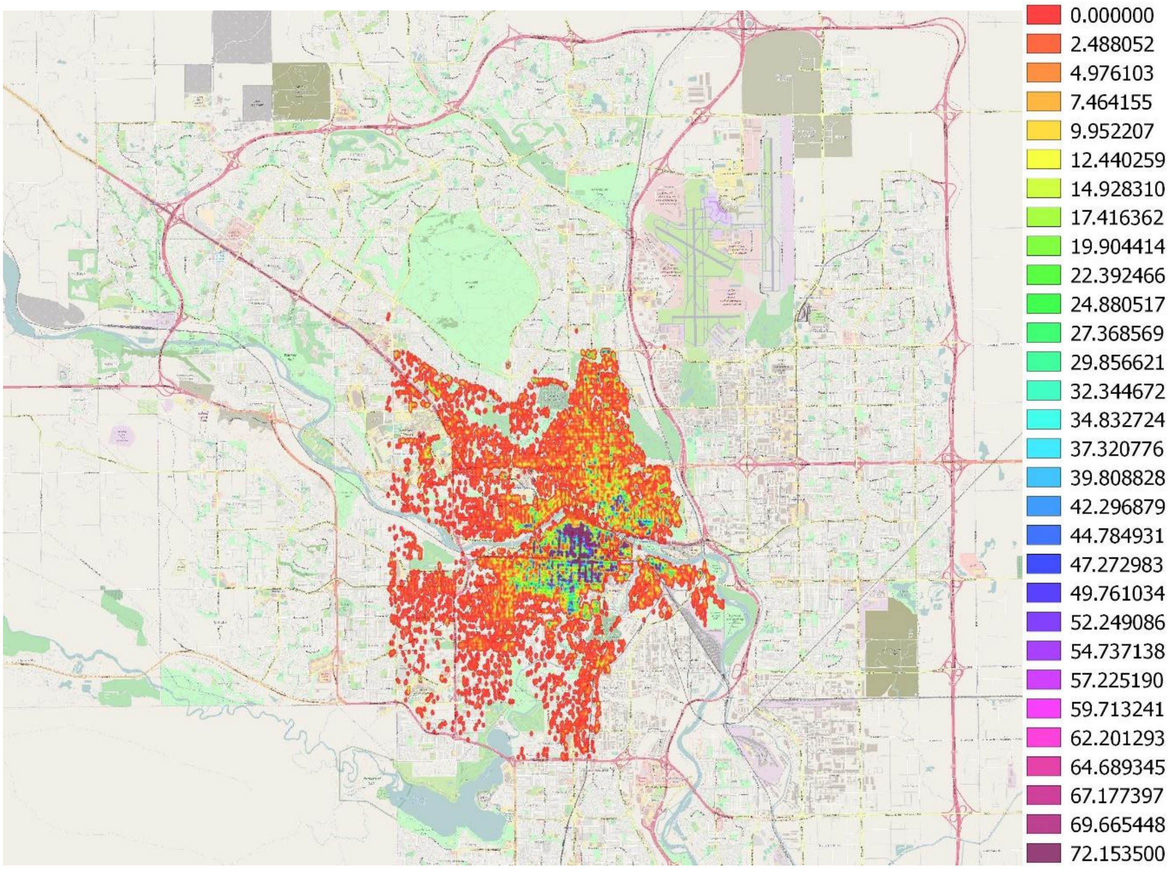
Appendix 1.3 (continued)

15:00:00 – 18:00:00	
	
18:00:00 – 21:00:00	
	
21:00:00 – 23:59:59	
	

Appendix 1.4: Heatmap of arrivals within 4 month based on a radius of 100 m



Berlin



Calgary

Appendix 1.5: Car traffic over the day and over the week

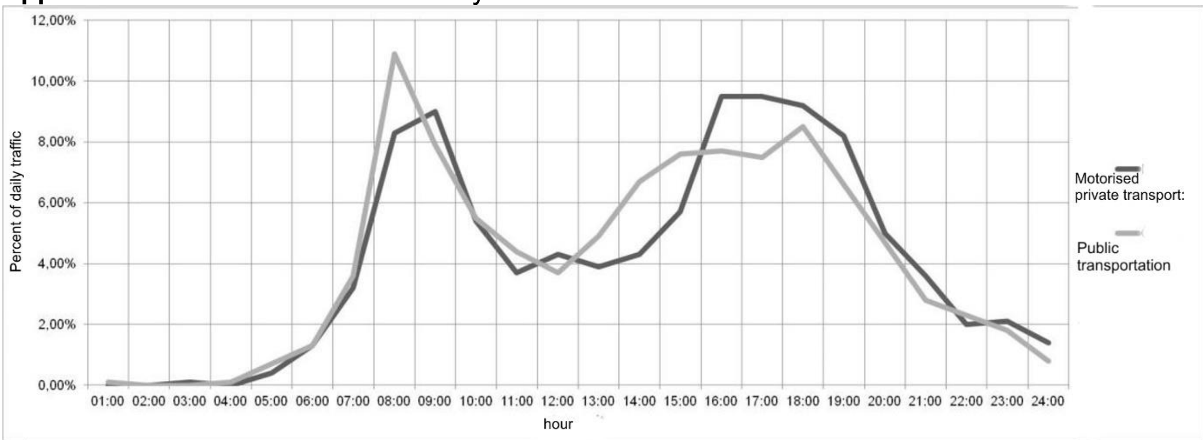


Figure Appendix 1.5_a: 24-hour traffic volume and public transportation data of people living within the Berlin Ringbahn
Figure adapted by author from: (Gehrke, 2016 p. 10)

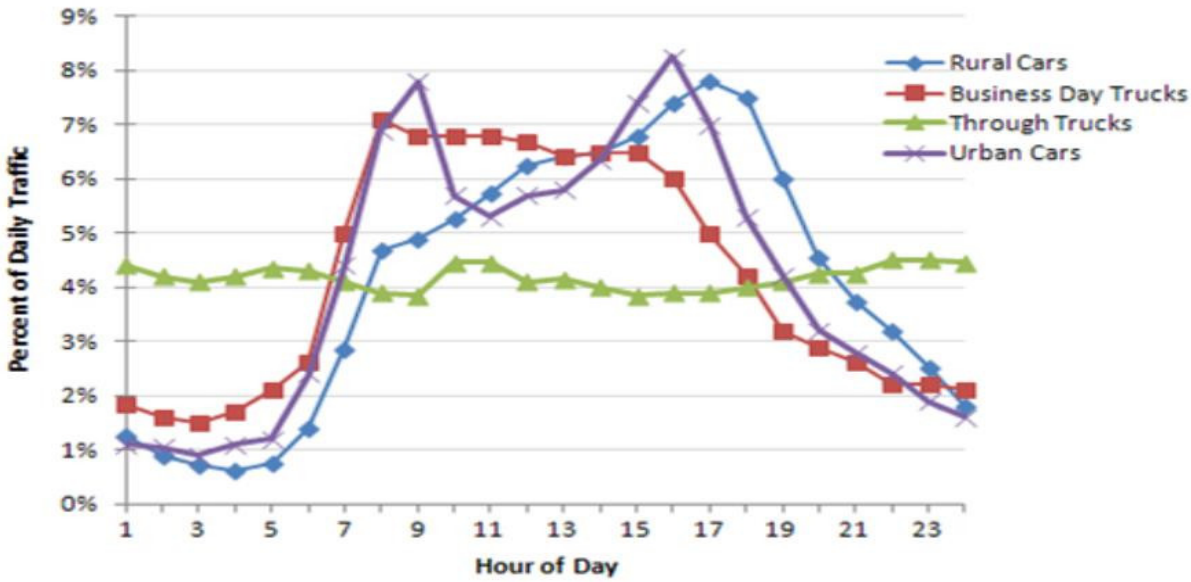


Figure Appendix 1.5_b: Typical 24-hour traffic volume data in rual and urban areas
Source: (U.S. Department of Transportation, 2014)

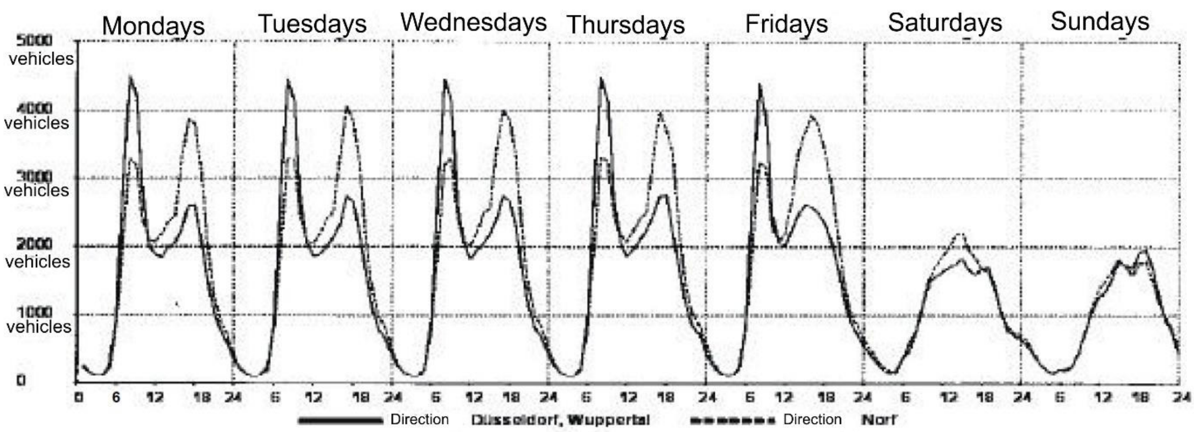


Figure Appendix 1.5_c: 168-hour (one week) traffic volume data (Germany)
Figure adapted by author from: (Zimmermann, et al., 2001 p. 7)

Appendix 1.5 (continued)

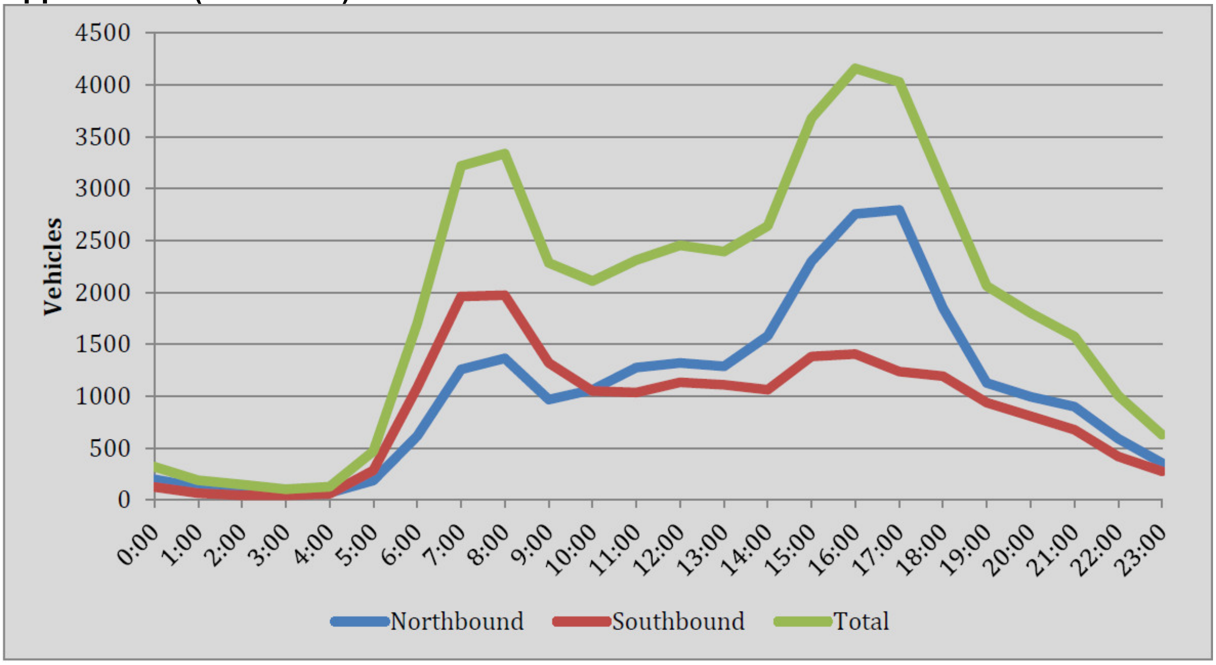


Figure Appendix 1.5_d: 24-hour traffic volume data (Calgary: 14 Street SW - North of 6 Avenue (Downtown))
Source: (Bunt & Associates Egineering (Alberta) Ltd., 2016 p. 17)

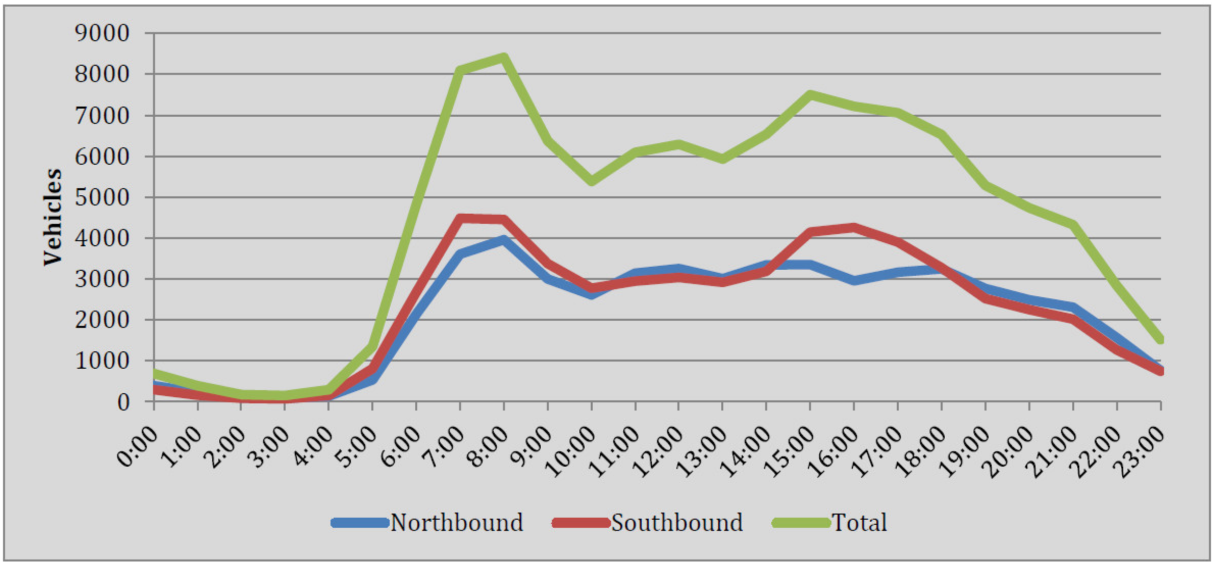


Figure Appendix 1.5_e: 24-hour traffic volume data (Calgary: Crowchild Trail NW – South of Bowness Road)
Source: (Bunt & Associates Egineering (Alberta) Ltd., 2016 p. 18)

2. CODE

Appendix 2.1: Data set up

```
----------------------------------------------------------
--create schema
----------------------------------------------------------
create schema if not exists wo16; -- create an empty schema
set datestyle to german;  -- depending on installation properties, date format has to be changed to german style
drop table if exists wo16.routes;
create table wo16.routes(   -- create an empty table within schema 'world' with primary key 'id' for global carsharing data
	id serial primary key,
	timestampstart timestamp default null,
	timestampend timestamp default null,
	provider character varying,
	vehicleid character varying,
	licenceplate character varying,
	model character varying,
	innercleanliness character varying,
	outercleanliness character varying,
	fueltype character varying,
	fuelstatestart character varying,
	fuelstateend character varying,
	chargingonstart character varying,
	chargingonend character varying,
	streetstart character varying,
	streetend character varying,
	latitudestart double precision,
	longitudestart double precision,
	latitudeend double precision,
longitudeend double precision);


----------------------------------------------------------
--import files
----------------------------------------------------------
copy wo16.routes (timestampstart, timestampend, provider, vehicleid, licenceplate, model, innercleanliness, outercleanliness, fueltype, fuelstatestart, fuelstateend, chargingonstart, chargingonend, streetstart, streetend, latitudestart, longitudestart, latitudeend, longitudeend)
from 'c:/users/uwe/documents/a - calgary/data/2016_2/drivenow/2016-08.csv' null as 'na' delimiter ';' ;

copy wo16.routes (timestampstart, timestampend, provider, vehicleid, licenceplate, model, innercleanliness, outercleanliness, fueltype, fuelstatestart, fuelstateend, chargingonstart, chargingonend, streetstart, streetend, latitudestart, longitudestart, latitudeend, longitudeend)
from 'c:/users/uwe/documents/a - calgary/data/2016_2/drivenow/2016-09.csv' null as 'na' delimiter ';' ;

copy wo16.routes (timestampstart, timestampend, provider, vehicleid, licenceplate, model, innercleanliness, outercleanliness, fueltype, fuelstatestart, fuelstateend, chargingonstart, chargingonend, streetstart, streetend, latitudestart, longitudestart, latitudeend, longitudeend)
from 'c:/users/uwe/documents/a - calgary/data/2016_2/car2go/2016-08.csv' null as 'na' delimiter ';' ;

copy wo16.routes (timestampstart, timestampend, provider, vehicleid, licenceplate, model, innercleanliness, outercleanliness, fueltype, fuelstatestart, fuelstateend, chargingonstart, chargingonend, streetstart, streetend, latitudestart, longitudestart, latitudeend, longitudeend)
from 'c:/users/uwe/documents/a - calgary/data/2016_2/car2go/2016-09.csv' null as 'na' delimiter ';' ;

copy wo16.routes (timestampstart, timestampend, provider, vehicleid, licenceplate, model, innercleanliness, outercleanliness, fueltype, fuelstatestart, fuelstateend, chargingonstart, chargingonend, streetstart, streetend, latitudestart, longitudestart, latitudeend, longitudeend)
from 'c:/users/uwe/documents/a - calgary/data/2016_2/car2go/2016-10.csv' null as 'na' delimiter ';' ;

copy wo16.routes (timestampstart, timestampend, provider, vehicleid, licenceplate, model, innercleanliness, outercleanliness, fueltype, fuelstatestart, fuelstateend, chargingonstart, chargingonend, streetstart, streetend, latitudestart, longitudestart, latitudeend, longitudeend)
from 'c:/users/uwe/documents/a - calgary/data/2016_2/car2go/2016-11.csv' null as 'na' delimiter ';' ;


----------------------------------------------------------
--ad world geo
----------------------------------------------------------
-- add line
alter table wo16.routes drop column if exists geom;
select  addgeometrycolumn(
	'wo16',
	'routes',
	'geom',
	4326,
	'linestring'
	,2);
update wo16.routes set geom = st_setsrid(st_makeline(st_point(longitudestart, latitudestart), st_point(longitudeend, latitudeend)), 4326);
drop index if exists idx_wo16_routes_geom;
create index idx_wo16_routes_geom on wo16.routes using gist(geom);
```

Appendix 2.1 (continued)

```
--add point geometry for start
alter table wo16.routes drop column if exists
geom_start;
select  addgeometrycolumn(
        'wo16',
        'routes',
        'geom_start',
        4326,
        'point'
        ,2);

update wo16.routes set geom_start =
st_setsrid(st_point(longitudestart, latitudestart),
4326);
drop index if exists idx_wo16_routes_geom_start;
create index idx_wo16_routes_geom_start on
wo16.routes using gist(geom_start);

--sdd point geometry for end
alter table wo16.routes drop column if exists
geom_end;
select  addgeometrycolumn(
        'wo16',
        'routes',
        'geom_end',
        4326,
        'point'
        ,2);

update wo16.routes set geom_end =
st_setsrid(st_point(longitudestart, latitudestart),
4326);
drop index if exists idx_wo16_routes_geom_end;
create index idx_wo16_routes_geom_end on
wo16.routes using gist(geom_end);



vacuum analyze wo16.routes;


----------------------------------------------------------
--add city
----------------------------------------------------------
alter table wo16.routes drop column if exists city;
alter table wo16.routes add column city character
varying;

update wo16.routes set city = 'berlin'
where st_dwithin(wo16.routes.geom_start,
st_geomfromtext('point(13.408333 52.518611)',
4326), 0.5);

update wo16.routes set city = 'muenchen'
where st_dwithin(wo16.routes.geom_start,
st_geomfromtext('point(11.575556 48.137222)',
4326), 0.5);

update wo16.routes set city = 'hamburg'
where st_dwithin(wo16.routes.geom_start,
st_geomfromtext('point(9.993333 53.550556)', 4326),
0.5);

update wo16.routes set city = 'frankfurt'
where st_dwithin(wo16.routes.geom_start,
st_geomfromtext('point(8.682222 50.110556)', 4326),
0.5);

update wo16.routes set city = 'stuttgart'
where st_dwithin(wo16.routes.geom_start,
st_geomfromtext('point(9.182778 48.775556)', 4326),
0.5);

update wo16.routes set city = 'koeln'
where st_dwithin(wo16.routes.geom_start,
st_geomfromtext('point(6.956944 50.938056)', 4326),
0.3);

update wo16.routes set city = 'duesseldorf'
where st_dwithin(wo16.routes.geom_start,
st_geomfromtext('point(6.782778 51.225556)', 4326),
0.3);

update wo16.routes set city = 'vancouver'
where st_dwithin(wo16.routes.geom_start,
st_geomfromtext('point(-123.12244 49.28098)',
4326), 0.5);

update wo16.routes set city = 'calgary'
where st_dwithin(wo16.routes.geom_start,
st_geomfromtext('point(-114.06049 51.04641)',
4326), 0.5);

update wo16.routes set city = 'seattle'
where st_dwithin(wo16.routes.geom_start,
st_geomfromtext('point(-122.331944 47.606111)',
4326), 0.5);

drop index if exists wo16.idx_wo16_routes_city;
create index idx_wo16_routes_city on
wo16.routes(city);

vacuum analyze wo16.routes;

----------------------------------------------------------
-- import in separate schema
----------------------------------------------------------
--Calgary
create schema if not exists ca16;
drop table if exists ca16.routes ;
select * into ca16.routes
from wo16.routes where city = 'calgary';

--berlin
create schema if not exists be16;
drop table if exists be16.routes ;
select * into be16.routes
from wo16.routes where city = 'berlin';


vacuum analyze be16.routes;

vacuum analyze ca16.routes;
```

Appendix 2.1 (continued)

```
----------------------------------------------------------
--create index
----------------------------------------------------------
drop index if exists be16.idx_be16_routes_id;
drop index if exists be16.idx_be16_routes_provider;
drop index if exists
be16.idx_be16_routes_timestampstart;
drop index if exists
be16.idx_be16_routes_timestampend;
create index idx_be16_routes_id on be16.routes(id);
create index idx_be16_routes_provider on
be16.routes(provider);
create index idx_be16_routes_timestampstart on
be16.routes(timestampstart);
create index idx_be16_routes_timestampend on
be16.routes(timestampend);

drop index if exists ca16.idx_ca16_routes_id;
drop index if exists ca16.idx_ca16_routes_provider;
drop index if exists
ca16.idx_ca16_routes_timestampstart;
drop index if exists
ca16.idx_ca16_routes_timestampend;
create index idx_ca16_routes_id on ca16.routes(id);
create index idx_ca16_routes_provider on
ca16.routes(provider);
create index idx_ca16_routes_timestampstart on
ca16.routes(timestampstart);
create index idx_ca16_routes_timestampend on
ca16.routes(timestampend);

vacuum analyze be16.routes;

vacuum analyze ca16.routes;



----------------------------------------------------------
--delete wrong things
----------------------------------------------------------
-- drop 'umrüsterfahrten'
select count(*) from be16.routes
where streetstart = 'umrüster de' or streetend =
'umrüster de' ;
-- drop wrong rentals
delete from be16.routes
where latitudestart < 1 or longitudestart < 1 or
latitudeend < 1 or longitudeend < 1 or
latitudestart > 90 or longitudestart > 90 or latitudeend
> 90 or longitudeend > 90;
delete from ca16.routes where longitudeend = '0';
delete from ca16.routes where latitudeend = '0';

vacuum analyze be16.routes;

vacuum analyze ca16.routes;
----------------------------------------------------------
-- add local geom
----------------------------------------------------------
-- berlin
alter table be16.routes drop column if exists
geom25833;
select  addgeometrycolumn(
            'be16',
            'routes',
            'geom25833',
            25833,
            'linestring'
            ,2);

update be16.routes set geom25833 =
st_transform(st_setsrid(st_makeline(st_point(longitud
estart, latitudestart), st_point(longitudeend,
latitudeend)), 4326), 25833);
drop index if exists idx_be16_routes_geom25833;
create index idx_be16_routes_geom25833 on
be16.routes using gist(geom25833);

alter table be16.routes drop column if exists
geom_start25833;
select  addgeometrycolumn(
            'be16',
            'routes',
            'geom_start25833',
            25833,
            'point'
            ,2);

update be16.routes set geom_start25833 =
st_transform(st_setsrid(st_point(longitudestart,
latitudestart), 4326), 25833);
drop index if exists
idx_be16_routes_geom_start25833;
create index idx_be16_routes_geom_start25833 on
be16.routes using gist(geom_start25833);

alter table be16.routes drop column if exists
geom_end25833;
select  addgeometrycolumn(
            'be16',
            'routes',
            'geom_end25833',
            25833,
            'point'
            ,2);

update be16.routes set geom_end25833 =
st_transform(st_setsrid(st_point(longitudeend,
latitudeend), 4326), 25833);
drop index if exists
idx_be16_routes_geom_end25833;
create index idx_be16_routes_geom_end25833 on
be16.routes using gist(geom_end25833)

-- calgary
alter table ca16.routes drop column if exists
geom3402;
select  addgeometrycolumn(
            'ca16',
            'routes',
            'geom3402',
            3402,
            'linestring'
            ,2);

update ca16.routes set geom3402 =
st_transform(st_setsrid(st_makeline(st_point(longitud
estart, latitudestart), st_point(longitudeend,
latitudeend)), 4326), 3402);
drop index if exists idx_ca16_routes_geom3402;
create index idx_ca16_routes_geom3402 on
ca16.routes using gist(geom3402);
```

Appendix 2.1 (continued)

```
alter table ca16.routes drop column if exists
geom_start3402;
select  addgeometrycolumn(
            'ca16',
            'routes',
            'geom_start3402',
            3402,
            'point'
            ,2);

update ca16.routes set geom_start3402 =
st_transform(st_setsrid(st_point(longitudestart,
latitudestart), 4326), 3402);
drop index if exists
idx_ca16_routes_geom_start3402;
create index idx_ca16_routes_geom_start3402 on
ca16.routes using gist(geom_start3402);


alter table ca16.routes drop column if exists
geom_end3402;
select  addgeometrycolumn(
            'ca16',
            'routes',
            'geom_end3402',
            3402,
            'point'
            ,2);

update ca16.routes set geom_end3402 =
st_transform(st_setsrid(st_point(longitudeend,
latitudeend), 4326), 3402);
drop index if exists
idx_ca16_routes_geom_end3402;
create index idx_ca16_routes_geom_end3402 on
ca16.routes using gist(geom_end3402)

vacuum analyze be16.routes;

vacuum analyze ca16.routes;

select count(*) from be16.routes;
select count(*) from ca16.routes;

----------------------------------------------------------
--calculate index
----------------------------------------------------------
--duration in minutes:
alter table be16.routes add column duration_min_b
double precision;
update be16.routes set duration_min_b =
extract(epoch from (timestampend -
timestampstart))/60 ;
drop index if exists
idx_be16_routes_duration_min_b;
create index idx_be16_routes_duration_min_b on
be16.routes(duration_min_b);

alter table ca16.routes add column duration_min_c
double precision;
update ca16.routes set duration_min_c =
extract(epoch from (timestampend -
timestampstart))/60 ;
drop index if exists idx_ca16_routes_duration_min_c;
create index idx_ca16_routes_duration_min_c on
ca16.routes(duration_min_c);
```

```
vacuum analyze be16.routes;

vacuum analyze ca16.routes;

--distance in meters (rounded to two decimal places,
column 'geom' have to be linestring
alter table be16.routes add column distance_m_b
double precision;
update be16.routes set distance_m_b =
round(st_length(st_transform(geom,25833))::numeric
,2);

alter table ca16.routes add column distance_m_c
double precision;
update ca16.routes set distance_m_c =
round(st_length(geom3402)::numeric,2);

vacuum analyze be16.routes;

vacuum analyze ca16.routes;

--mean speed in km/h
alter table be16.routes add column mean_speed_b
double precision;
update be16.routes set mean_speed_b = case
  when duration_min_b > 0
then(distance_m_b/1000)/(duration_min_b/60)
  else 99999
end;

drop index if exists idx_be16_routes_speed;
create index idx_be16_routes_speed on
be16.routes(mean_speed_b);

alter table ca16.routes add column mean_speed_c
double precision;
update ca16.routes set mean_speed_c = case
  when duration_min_c > 0
then(distance_m_c/1000)/(duration_min_c/60)
  else 99999
end;

drop index if exists idx_ca16_routes_speed;
create index idx_ca16_routes_speed on
ca16.routes(mean_speed_c);

vacuum analyze be16.routes;

vacuum analyze ca16.routes;
```

Appendix 2.2: Time frame

```
------------------------------------------------------------
--time frame
------------------------------------------------------------
select * from be16.routes order by timestampstart
asc limit 1000;
select * from be16.routes order by timestampend
desc limit 1000;
```

Appendix 2.3: Data cleaning

```
----------------------------------------------------------
--Delete wrong things
----------------------------------------------------------
-- longer than maximal rental period
delete from ca16.routes where duration_min_c >
4320;
delete from be16.routes where duration_min_b >
1440 and provider = 'car2go';
delete from be16.routes where duration_min_b >
2880;
--high average speed
delete from ca16.routes where mean_speed_c >
180;
delete from be16.routes where mean_speed_b >
180;
--traveled distance=0 km
delete from ca16.routes where distance_m_c = 0;
delete from be16.routes where distance_m_b = 0;
--time just 0 minutes
delete from ca16.routes where duration_min_c = 0;
delete from be16.routes where duration_min_b = 0;

vacuum analyze be16.routes;

vacuum analyze ca16.routes;

----------------------------------------------------------
--percentage of deleted rentals
----------------------------------------------------------
--number of rentals in original dataset
select count(*) from wo16.routes where city = 'berlin';
select count(*) from wo16.routes where city =
'calgary';

--number of rentals after data cleaning
select count(*) from be16.routes;
select count(*) from ca16.routes;
```

Appendix 2.4: Limitations

```
--------------------------------------------------------
--cars to 124 east lake blvd ne, airdrie, ab t4a 2g2
--------------------------------------------------------
--number of trips
select count(*) from ca16.routes where streetstart =
'124 east lake blvd ne, airdrie, ab t4a 2g2';

--first and last timepoint of these trips
select * from ca16.routes where streetstart = '124
east lake blvd ne, airdrie, ab t4a 2g2' order by
timestampstart;
select * from ca16.routes where streetstart = '124
east lake blvd ne, airdrie, ab t4a 2g2' order by
licenceplate;

--first trip of each car
select * from ca16.routes where licenceplate =
'l41136' order by timestampstart;
select * from ca16.routes where licenceplate =
'l41137' order by timestampstart;
select * from ca16.routes where licenceplate =
'l41139' order by timestampstart;
select * from ca16.routes where licenceplate =
'l41120' order by timestampstart;
select * from ca16.routes where licenceplate =
'l41129' order by timestampstart;
select * from ca16.routes where licenceplate =
'l41130' order by timestampstart;
select * from ca16.routes where licenceplate =
'l41123' order by timestampstart;
select * from ca16.routes where licenceplate =
'l41113' order by timestampstart;
select * from ca16.routes where licenceplate =
'l80352' order by timestampstart;
select * from ca16.routes where licenceplate =
'l41147' order by timestampstart;
…
--round trip from and to airdrie
select count(distinct vehicleid) from ca16.routes
where streetstart = '124 east lake blvd ne, airdrie, ab
t4a 2g2';
select * from ca16.routes where streetstart = '124
east lake blvd ne, airdrie, ab t4a 2g2' and streetend =
'124 east lake blvd ne, airdrie, ab t4a 2g2';

--------------------------------------------------------
--arrivals and departures in each hexagon
--------------------------------------------------------
--add hexagon
alter table be16.routes drop column if exits start_hex;
alter table be16.routes drop column if exits end_hex;
alter table ca16.routes drop column if exits start_hex;
alter table ca16.routes drop column if exits end_hex;

alter table be16.routes add column start_hex integer;
alter table be16.routes add column end_hex integer;
update be16.routes set start_hex = gid from
be16.hexagon_25833_b where
st_within(be16.routes.geom_start25833,
be16.hexagon_25833_b.geom);
update be16.routes set end_hex = gid from
be16.hexagon_25833_b where
st_within(be16.routes.geom_end25833,
be16.hexagon_25833_b.geom);

alter table ca16.routes add column start_hex integer;
alter table ca16.routes add column end_hex integer;
update ca16.routes set start_hex = gid from
ca16.hexagon_3402_c where
st_within(ca16.routes.geom_start3402,
ca16.hexagon_3402_c.geom);
update ca16.routes set end_hex = gid from
ca16.hexagon_3402_c where
st_within(ca16.routes.geom_end3402,
ca16.hexagon_3402_c.geom);

vacuum analyze be16.routes;
vacuum analyze ca16.routes;

--export
copy(
select start_hex from be16.routes where
timestampstart::time >= '00:00:00' and
timestampstart::time < '03:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_0-
3_start.csv' delimiter ';' csv header;

copy(
select start_hex from be16.routes where
timestampstart::time >= '03:00:00' and
timestampstart::time < '06:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_3-
6_start.csv' delimiter ';' csv header;

copy(
select start_hex from be16.routes where
timestampstart::time >= '06:00:00' and
timestampstart::time < '09:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_6-
9_start.csv' delimiter ';' csv header;

copy(
select start_hex from be16.routes where
timestampstart::time >= '09:00:00' and
timestampstart::time < '12:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_9-
12_start.csv' delimiter ';' csv header;

copy(
select start_hex from be16.routes where
timestampstart::time >= '12:00:00' and
timestampstart::time < '15:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_12-
15_start.csv' delimiter ';' csv header;

copy(
select start_hex from be16.routes where
timestampstart::time >= '15:00:00' and
timestampstart::time < '18:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_15-
18_start.csv' delimiter ';' csv header;

copy(
select start_hex from be16.routes where
timestampstart::time >= '18:00:00' and
timestampstart::time < '21:00:00')
```

Appendix 2.4 (continued)

```
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_18-
21_start.csv' delimiter ';' csv header;

copy(
select start_hex from be16.routes where
timestampstart::time >= '21:00:00' and
timestampstart::time <= '23:59:59')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_21-
24_start.csv' delimiter ';' csv header;

copy(
select end_hex from be16.routes where
timestampend::time >= '00:00:00' and
timestampend::time < '03:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_0-
3_end.csv' delimiter ';' csv header;

copy(
select end_hex from be16.routes where
timestampend::time >= '03:00:00' and
timestampend::time < '06:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_3-
6_end.csv' delimiter ';' csv header;

copy(
select end_hex from be16.routes where
timestampend::time >= '06:00:00' and
timestampend::time < '09:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_6-
9_end.csv' delimiter ';' csv header;

copy(
select end_hex from be16.routes where
timestampend::time >= '09:00:00' and
timestampend::time < '12:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_9-
12_end.csv' delimiter ';' csv header;

copy(
select end_hex from be16.routes where
timestampend::time >= '12:00:00' and
timestampend::time < '15:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_12-
15_end.csv' delimiter ';' csv header;

copy(
select end_hex from be16.routes where
timestampend::time >= '15:00:00' and
timestampend::time < '18:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_15-
18_end.csv' delimiter ';' csv header;

copy(
select end_hex from be16.routes where
timestampend::time >= '18:00:00' and
timestampend::time < '21:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_18-
21_end.csv' delimiter ';' csv header;

copy(
select end_hex from be16.routes where
timestampend::time >= '21:00:00' and
timestampend::time <= '23:59:59')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_b_21-
24_end_neu.csv' delimiter ';' csv header;

copy(
select start_hex from ca16.routes where
timestampstart::time >= '08:00:00' and
timestampstart::time < '11:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_0-
3_start.csv' delimiter ';' csv header;

copy(
select start_hex from ca16.routes where
timestampstart::time >= '11:00:00' and
timestampstart::time < '14:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_3-
6_start.csv' delimiter ';' csv header;

copy(
select start_hex from ca16.routes where
timestampstart::time >= '14:00:00' and
timestampstart::time < '17:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_6-
9_start.csv' delimiter ';' csv header;

copy(
select start_hex from ca16.routes where
timestampstart::time >= '17:00:00' and
timestampstart::time < '20:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_9-
12_start.csv' delimiter ';' csv header;

copy(
select start_hex from ca16.routes where
timestampstart::time >= '20:00:00' and
timestampstart::time < '23:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_12-
15_start.csv' delimiter ';' csv header;

copy(
select start_hex from ca16.routes where
timestampstart::time >= '23:00:00' and
timestampstart::time <= '23:59:59')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_15-
18_start_part1.csv' delimiter ';' csv header;
copy(
select start_hex from ca16.routes where
timestampstart::time >= '00:00:00' and
timestampstart::time < '02:00:0')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_15-
18_start_part2.csv' delimiter ';' csv header;
```

Appendix 2.4 (continued)

```
copy(
select start_hex from ca16.routes where
timestampstart::time >= '02:00:00' and
timestampstart::time < '05:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_18-
21_start.csv' delimiter ';' csv header;

copy(
select start_hex from ca16.routes where
timestampstart::time >= '05:00:00' and
timestampstart::time < '08:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_21-
24_start.csv' delimiter ';' csv header;



copy(
select end_hex from ca16.routes where
timestampend::time >= '08:00:00' and
timestampend::time < '11:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_0-
3_end.csv' delimiter ';' csv header;

copy(
select end_hex from ca16.routes where
timestampend::time >= '11:00:00' and
timestampend::time < '14:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_3-
6_end.csv' delimiter ';' csv header;

copy(
select end_hex from ca16.routes where
timestampend::time >= '14:00:00' and
timestampend::time < '17:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_6-
9_end.csv' delimiter ';' csv header;

copy(
select end_hex from ca16.routes where
timestampend::time >= '17:00:00' and
timestampend::time < '20:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_9-
12_end.csv' delimiter ';' csv header;

copy(
select end_hex from ca16.routes where
timestampend::time >= '20:00:00' and
timestampend::time < '23:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_12-
15_end.csv' delimiter ';' csv header;

copy(
select end_hex from ca16.routes where
timestampend::time >= '23:00:00' and
timestampend::time <= '23:59:59')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_15-
18_end_part1.csv' delimiter ';' csv header;

copy(
select end_hex from ca16.routes where
timestampend::time >= '00:00:00' and
timestampend::time <= '02:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_15-
18_end_part2.csv' delimiter ';' csv header;
copy(
select end_hex from ca16.routes where
timestampend::time >= '02:00:00' and
timestampend::time < '05:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_18-
21_end.csv' delimiter ';' csv header;

copy(
select end_hex from ca16.routes where
timestampend::time >= '05:00:00' and
timestampend::time < '08:00:00')
to 'c:/program
files/postgresql/9.5/data/geo/hexagon_matrix_c_21-
24_end.csv' delimiter ';' csv header;

-----------------------------------------------------------
--number of cars
-----------------------------------------------------------
select count(distinct vehicleid) from be16.routes;
select count(distinct vehicleid) from ca16.routes;
```

Appendix 2.5: average and percentile

```
--mean
select avg(distance_m_b) from be16.routes;
select avg(distance_m_c) from ca16.routes;

select avg(duration_min_b) from be16.routes;
select avg(duration_min_c) from ca16.routes;

select avg(mean_speed_b) from be16.routes;
select avg(mean_speed_c) from ca16.routes;


--standartdiviation
select stddev_samp(distance_m_b) from
be16.routes;
select stddev_samp(distance_m_c) from
ca16.routes;

select stddev_samp(duration_min_b) from
be16.routes;
select stddev_samp(duration_min_c) from
ca16.routes;

select stddev_samp(mean_speed_b) from
be16.routes;
select stddev_samp(mean_speed_c) from
ca16.routes;

--mode
SELECT mode() WITHIN GROUP (ORDER BY
Duration_min_c) AS modal_value FROM
Ca16.routes;
SELECT mode() WITHIN GROUP (ORDER BY
Duration_min_b) AS modal_value FROM
be16.routes;


--percentile 10
select percentile_disc(0.1) within group (order by
distance_m_b)
 from be16.routes;
select percentile_disc(0.1) within group (order by
distance_m_c)
 from ca16.routes;

 select percentile_disc(0.1) within group (order by
duration_min_b)
 from be16.routes;
select percentile_disc(0.1) within group (order by
duration_min_c)
 from ca16.routes;

select percentile_disc(0.1) within group (order by
mean_speed_b)
 from be16.routes;
select percentile_disc(0.1) within group (order by
mean_speed_c)
 from ca16.routes;


 --percentile 25
select percentile_disc(0.25) within group (order by
distance_m_b)
 from be16.routes;
select percentile_disc(0.25) within group (order by
distance_m_c)
 from ca16.routes;

 select percentile_disc(0.25) within group (order by
duration_min_b)
 from be16.routes;
select percentile_disc(0.25) within group (order by
duration_min_c)
 from ca16.routes;

select percentile_disc(0.25) within group (order by
mean_speed_b)
 from be16.routes;
select percentile_disc(0.25) within group (order by
mean_speed_c)
 from ca16.routes;


 --percentile 50 / median
select percentile_disc(0.5) within group (order by
distance_m_b)
 from be16.routes;
select percentile_disc(0.5) within group (order by
distance_m_c)
 from ca16.routes;

 select percentile_disc(0.5) within group (order by
duration_min_b)
 from be16.routes;
select percentile_disc(0.5) within group (order by
duration_min_c)
 from ca16.routes;

select percentile_disc(0.5) within group (order by
mean_speed_b)
 from be16.routes;
select percentile_disc(0.5) within group (order by
mean_speed_c)
 from ca16.routes;


 --percentile 75
select percentile_disc(0.75) within group (order by
distance_m_b)
 from be16.routes;
select percentile_disc(0.75) within group (order by
distance_m_c)
 from ca16.routes;

 select percentile_disc(0.75) within group (order by
duration_min_b)
 from be16.routes;
select percentile_disc(0.75) within group (order by
duration_min_c)
 from ca16.routes

select percentile_disc(0.75) within group (order by
mean_speed_b)
 from be16.routes
select percentile_disc(0.75) within group (order by
mean_speed_c)
 from ca16.routes


 --percentile 90
select percentile_disc(0.9) within group (order by
distance_m_b)
 from be16.routes
```

Appendix 2.5 (continued)

```
select percentile_disc(0.9) within group (order by
distance_m_c)
  from ca16.routes

  select percentile_disc(0.9) within group (order by
duration_min_b)
  from be16.routes
select percentile_disc(0.9) within group (order by
duration_min_c)
  from ca16.routes

select percentile_disc(0.9) within group (order by
mean_speed_b)
  from be16.routes
select percentile_disc(0.9) within group (order by
mean_speed_c)
  from ca16.routes
```

Appendix 2.6: Calculate histograms

1. export data from PostreSQL

```
copy (select * from be16.routes)
to 'c:/program
files/postgresql/9.5/data/16/all_b.csv' delimiter ';'
csv header;

copy (select * from ca16.routes)
to 'c:/program
files/postgresql/9.5/data/16/all_c.csv' delimiter ';'
csv header;
```

2. Calculate histograms in R

```
#Distance
#Calculate minimum and maximum (Berlin)
range(all_B$distance_m_b)
#Calculate minimum and maximum (Calgary)
range(all_C$distance_m_c)
#define bins seq(min, max, by=bin with)
bins_m =seq(0, 600000, by=200)
#calculate histogram (Berlin)
hist(all_B$distance_m_b, breaks = bins_m)
#copy hexagon to .txt (Berlin)
sink("B_Bin_ distance_m_b.txt")
print(hist(all_B$ distance_m_b, breaks = bins_m))
sink()
#calculate histogram (Calgary)
hist(all_C$distance_m_c, breaks = bins_m)
#copy hexagon to .txt (Calgary)
sink("C_Bin_ distance_m_c.txt")
print(hist(all_C$distance_m_c, breaks = bins_m))
sink()

#Duration
#Calculate minimum and maximum (Berlin)
range(all_B$duration_min_b)
#Calculate minimum and maximum (Calgary)
range(all_c$duration_min_c)
#define bins seq(min, max, by=bin with)
bins_min = seq(0, 4500, by=3)
#calculate histogram (Berlin)
hist(all_B$duration_min_b, breaks = bins_min)
#copy hexagon to .txt (Berlin)
sink("B_Bin_duration_min_B.txt")
print(hist(all_B$duration_min_b, breaks =
bins_min))
sink()
#calculate histogram (Calgary)
hist(all_C$duration_min_c, breaks = bins_min)
#copy hexagon to .txt (Calgary)
sink("c_Bin_duration_min_c.txt")
print(hist(all_C$duration_min_c, breaks =
bins_min))
sink()

#Mean_speed
#Calculate minimum and maximum (Berlin)
range(all_B$mean_speed_b)
#Calculate minimum and maximum (Calgary)
range(all_C$mean_speed_c)
#define bins seq(min, max, by=bin with)
bins_kmh =seq(0, 200, by=1)
#calculate histogram (Berlin)
hist(all_B$ mean_speed_b, breaks = bins_kmh)
#copy hexagon to .txt (Berlin)
sink("B_Bin_ distance_m_b.txt")
print(hist(all_B$mean_speed_b, breaks =
bins_kmh))
sink()
#calculate histogram (Calgary)
hist(all_C$ mean_speed_c, breaks = bins_kmh)
#copy hexagon to .txt (Calgary)
sink("C_Bin_ mean_speed_c.txt")
print(hist(all_C$mean_speed_c, breaks =
bins_kmh))
sink()
```

Appendix 2.7: Carsharing bookings over the week

1. Export data from PostgreSQL

```
--weekly
copy(
select count(*), extract(isodow from
timestampstart) as dow,
extract(hour from timestampstart) as hour,
extract(minute from timestampstart) as minute
from be16.routes
group by dow, hour, minute
order by dow, hour, minute)
to 'c:/program
files/postgresql/9.5/data/16/weekly_b.csv'
delimiter ';' csv header;

copy(
select count(*), extract(isodow from
timestampstart) as dow,
extract(hour from timestampstart) as hour,
extract(minute from timestampstart) as minute
from ca16.routes
group by dow, hour, minute
order by dow, hour, minute)
to 'c:/program
files/postgresql/9.5/data/16/weekly_c.csv'
delimiter ';' csv header;
```

Appendix 2.8: Geographic analysis

1. Departure and arrival points
See Appendix 2.4:

2. Connecting trips between hexagons

```
copy(
select start_hex,end_hex, count(*) from
be16.routes group by start_hex, end_hex order by
start_hex, end_hex)
to 'c:/program
files/postgresql/9.5/data/hexagon_matrix_lines_b.
csv' delimiter ';' csv header;

copy(
select start_hex,end_hex, count(*) from
ca16.routes group by start_hex, end_hex order by
start_hex, end_hex)
to 'c:/program
files/postgresql/9.5/data/hexagon_matrix_lines_c.
csv' delimiter ';' csv header;
```

3. Per cent of trips to and from …

```
select count(*) from ca16.routes;

--from and to hexagon 504
select count(*) from ca16.routes where end_hex =
'504';
select count(*) from ca16.routes where not
end_hex = '504' and not start_hex = '504';
select count(*) from ca16.routes where start_hex
= '504' and end_hex = '504';
select count(*) from ca16.routes where start_hex
= '504' and not end_hex = '504';
select count(*) from ca16.routes where end_hex =
'504' and not start_hex = '504';
select count(*) from ca16.routes;

--from and to downtown
select count(*) from ca16.routes
where not start_hex = '478'
and not start_hex = '479'
and not start_hex = '503'
and not start_hex = '504'
and not start_hex = '505'
and not start_hex = '530'
and not start_hex = '531'
and not end_hex = '478'
and not end_hex = '479'
and not end_hex = '503'
and not end_hex = '504'
and not end_hex = '505'
and not end_hex = '530'
and not end_hex = '531';

select count(*) from ca16.routes
where start_hex = '478'
or start_hex = '479'
or start_hex = '503'
or start_hex = '504'
or start_hex = '505'
or start_hex = '530'
or start_hex = '531'
or end_hex = '478'
or end_hex = '479'
or end_hex = '503'
or end_hex = '504'
or end_hex = '505'
or end_hex = '530'
or end_hex = '531';
```

4. from and to downtown or Calgary International Airport or University of Calgary

```
select count(*) from ca16.routes
where not start_hex = '478'
and not start_hex = '479'
and not start_hex = '503'
and not start_hex = '504'
and not start_hex = '505'
and not start_hex = '530'
and not start_hex = '531'
and not start_hex = '617'
and not start_hex = '618'
and not start_hex = '376'
and not start_hex = '377'
and not end_hex = '478'
and not end_hex = '479'
and not end_hex = '503'
and not end_hex = '504'
and not end_hex = '505'
and not end_hex = '530'
and not end_hex = '531'
and not end_hex = '617'
and not end_hex = '618'
and not end_hex = '376'
and not end_hex = '377';

select count(*) from ca16.routes
where start_hex = '478'
or start_hex = '479'
or start_hex = '503'
or start_hex = '504'
or start_hex = '505'
or start_hex = '530'
or start_hex = '531'
or start_hex = '617'
or start_hex = '618'
or start_hex = '376'
or start_hex = '377'
or end_hex = '478'
or end_hex = '479'
or end_hex = '503'
or end_hex = '504'
or end_hex = '505'
or end_hex = '530'
or end_hex = '531'
or end_hex = '617'
or end_hex = '618'
or end_hex = '376'
or end_hex = '377';
```

Appendix 2.9: Specific analysis for Chapter 6

1. midday peak

```
select count(*) from Ca16.routes where
distance_m_c <= '200' and  timestampstart::time
>= '15:00:00' and timestampstart::time <
'18:00:00';

select count(*) from Ca16.routes where
distance_m_c <= '200' and  timestampstart::time
>= '18:00:00' and timestampstart::time <
'21:00:00';

select count(*) from Ca16.routes where
distance_m_c <= '200' and  timestampstart::time
>= '21:00:00' and timestampstart::time <
'23:59:59';

select count(*) from Ca16.routes where
timestampstart::time >= '15:00:00' and
timestampstart::time < '18:00:00';

select count(*) from Ca16.routes where
timestampstart::time >= '18:00:00' and
timestampstart::time < '21:00:00';

select count(*) from Ca16.routes where
timestampstart::time >= '21:00:00' and
timestampstart::time < '23:59:59';
```

2. 3-Minute-long rentals

```
select count(*) from Ca16.routes where
duration_min_c <= '3' and  timestampstart::time
>= '09:00:00' and timestampstart::time <
'12:00:00';
select count(*) from Ca16.routes where
duration_min_c <= '3' and  timestampstart::time
>= '12:00:00' and timestampstart::time <
'15:00:00';
select count(*) from Ca16.routes where
duration_min_c <= '3' and  timestampstart::time
>= '15:00:00' and timestampstart::time <
'18:00:00';
select count(*) from Ca16.routes where
duration_min_c <= '3' and  timestampstart::time
>= '18:00:00' and timestampstart::time <
'21:00:00';
select count(*) from Ca16.routes where
duration_min_c <= '3' and  timestampstart::time
>= '21:00:00' and timestampstart::time <=
'23:59:59';
select count(*) from Ca16.routes where
duration_min_c <= '3' and  timestampstart::time
>= '00:00:00' and timestampstart::time <
'03:00:00';
select count(*) from Ca16.routes where
duration_min_c <= '3' and  timestampstart::time
>= '03:00:00' and timestampstart::time <
'06:00:00';
select count(*) from Ca16.routes where
duration_min_c <= '3' and  timestampstart::time
>= '06:00:00' and timestampstart::time <
'09:00:00';
select count(*) from Ca16.routes where
duration_min_c <= '3';
```

```
select count(*) from Ca16.routes where
timestampstart::time >= '09:00:00' and
timestampstart::time < '12:00:00';
select count(*) from Ca16.routes where
timestampstart::time >= '12:00:00' and
timestampstart::time < '15:00:00';
select count(*) from Ca16.routes where
timestampstart::time >= '15:00:00' and
timestampstart::time < '18:00:00';
select count(*) from Ca16.routes where
timestampstart::time >= '18:00:00' and
timestampstart::time < '21:00:00';
select count(*) from Ca16.routes where
timestampstart::time >= '21:00:00' and
timestampstart::time <= '23:59:59';
select count(*) from Ca16.routes where
timestampstart::time >= '00:00:00' and
timestampstart::time < '03:00:00';


select count(*) from Ca16.routes where
timestampstart::time >= '03:00:00' and
timestampstart::time < '06:00:00';
select count(*) from Ca16.routes where
timestampstart::time >= '06:00:00' and
timestampstart::time < '09:00:00';
select count(*) from Ca16.routes ;

select count(*)
  from ca16.routes where   timestampstart::time >=
'09:00:00' and timestampstart::time < '10:00:00'
and duration_min_c = '3'; 517
select count(*)
  from ca16.routes where   timestampstart::time >=
'10:00:00' and timestampstart::time < '11:00:00'
and duration_min_c = '3'; 3190
select count(*)
  from ca16.routes where   timestampstart::time >=
'11:00:00' and timestampstart::time < '12:00:00'
and duration_min_c = '3'; 317

select count(*)
  from ca16.routes where   timestampstart::time >=
'09:00:00' and timestampstart::time < '10:00:00';
select count(*)
  from ca16.routes where   timestampstart::time >=
'10:00:00' and timestampstart::time < '11:00:00';

select count(*)
  from ca16.routes where   timestampstart::time >=
'11:00:00' and timestampstart::time < '12:00:00';
```